DOCUMENT RESUME

ED 220 629 CE 033 514

AUTHOR Foutes, William; And Others
TITLE Diesel Mechanics: Fundamentals.
INSTITUTION Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE 82
NOTE 1,060p.; For related documents see ED 149 162 and CE 033 515-516.
AVAILABLE FROM Mid-America Vocational Curriculum Consortium, 1515 West Sixth Avenue, Stillwater, OK 74074.

EDRS PRICE MF08 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Auto Mechanics; Behavioral Objectives; Curriculum Guides; *Diesel Engines; Fuels; Job Skills; Learning Activities; Performance Tests; Postsecondary Education; Safety; Trade and Industrial Education; Transparencies; *Welding

ABSTRACT

This publication is the first in a series of three texts for a diesel mechanics curriculum. Its purpose is to teach the basic concepts related to employment in a diesel trade. Six sections contain 29 units. Each instructional unit includes some or all of these basic components: unit and specific (performance) objectives, suggested activities for teachers and students, information sheets, transparency masters, assignment sheets, answers to assignment sheets, job sheets, pencil-paper and performance tests, and answers to tests. Introductory materials include description of unit components, instructional/task analysis (psychomotor and cognitive skills to be learned), listing of needed tools and equipment, and reference list. Section topics are orientation (safety, basic shop tools and equipment), operating principles (diesel fuels, engine lubricants, coolants, bearings, seals), engine components (cylinder head assembly, piston and connecting rod assemblies, camshafts, gear train, engine timing, frames, cylinder blocks, crankshafts, bearings), auxiliary systems (lubrication, cooling, air intake and exhaust, starting, brakes and retarders), engine performance (operation and maintenance, diagnosis and testing, tune-up and adjustment, storage), and welding (arc and oxyacetylene). (YLB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED220629

DIESEL MECHANICS : FUNDAMENTALS

by

William Foutes

revised by

Bill Guynes
Joe Mathis
Marvin Kukuk

Developed by the

Mid-America Vocational Curriculum Consortium, Inc.

Board of Directors

Merle Rudebusch, Nebraska, Chairman
David Poston, Louisiana, Vice Chairman
Amon Herd, Missouri, Parliamentarian
James Dasher, Arkansas
Bill Barnes, Colorado
Les Abel, Kansas
Pat Lindley, Texas
Dan Elwood, South Dakota
Bob Patton, Oklahoma
Alan Morgan, New Mexico
Larry Barnhardt, North Dakota
Ann Benson, Executive Director

CE033514

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- **Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.**

"PERMISSION TO REPRODUCE THIS MATERIAL IN **MICROFICHE ONLY** HAS BEEN GRANTED BY

S Dean

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

82-000867

COPYRIGHT - 1982

Mid-America Vocational Curriculum Consortium, Inc.

Printed by

Oklahoma State Department of Vocational and Technical Education
Stillwater, Oklahoma 74074

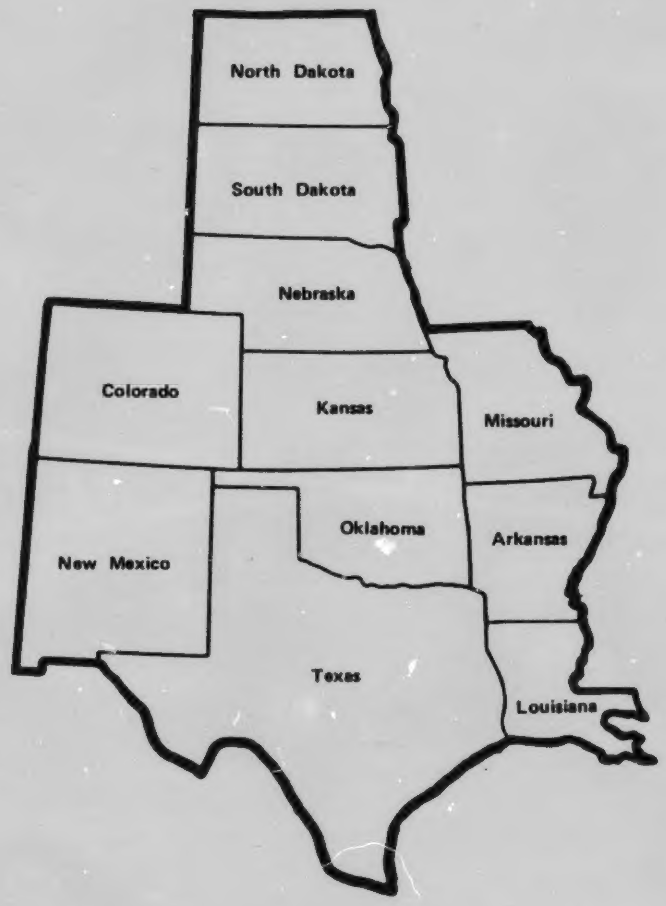

North Dakota
South Dakota
Nebraska
Colorado
Kansas
Missouri
New Mexico
Oklahoma
Arkansas
Texas
Louisiana

TABLE OF CONTENTS

Section A--Orientation

Unit I Introduction to Diesel . . . . D:F - 1-A
Unit II Shop Safety . . . . D:F - 19-A
Unit III Basic Shop Tools . . . . D:F - 41-A
Unit IV Test Equipment and Service Tools . . . . D:F - 163-A
Unit V Fasteners . . . . D:F - 199-A

Section B--Operating Principles

Unit I Engine Operating Principles . . . . D:F - 1-B
Unit II Diesel Fuels . . . . D:F - 45-B
Unit III Engine Lubricants . . . . D:F - 69-B
Unit IV Coolants . . . . D:F - 87-B
Unit V Bearings . . . . D:F - 109-B
Unit VI Seals . . . . D:F - 171-B

Section C--Engine Components

Unit I Cylinder Head Assembly . . . . D:F - 1-C
Unit II Piston and Connecting Rod Assemblies . . . . D:F - 61-C
Unit III Camshafts, Gear Train, and Engine Timing . . . . D:F - 111-C
Unit IV Frames and Cylinder Blocks . . . . D:F - 153-C
Unit V Crankshafts and Bearings . . . . D:F - 173-C

Section D--Auxiliary Systems

Unit I Lubrication Systems . . . . D:F - 1-D
Unit II Cooling Systems . . . . D:F - 45-D
Unit III Air Intake and Exhaust Systems . . . . D:F - 91-D
Unit IV Starting Systems . . . . D:F - 159-D
Unit V Engine Brakes and Retarders . . . . D:F - 185-D

Section E--Engine Performance

Unit I Operation and Maintenance . . . . D:F - 1-E
Unit II Diagnosis and Testing of Engines . . . . D:F - 21-E
Unit III Tune-up and Adjustment . . . . D:F - 55-E
Unit IV Engine Storage . . . . D:F - 97-E

Section F--Welding

Unit I Arc Welding . . . . D:F - 1-F
Unit II Oxyacetylene Cutting . . . . D:F - 47-F
Unit III Oxyacetylene Fusion Welding . . . . D:F - 81-F
Unit IV Oxyacetylene Braze Welding . . . . D:F - 113-F

FOREWORD

The Mid-America Vocational Curriculum Consortium (MAVCC) was organized for the purpose of developing instructional materials for its eleven member states. All member states participate in establishing annual development priorities, and the need for curriculum in diesel mechanics truly reflects regional needs.

Diesel Engine Mechanics was originally produced in 1977. Since that time, technology as related to equipment and methods has changed. To keep abreast of these changes, MAVCC has revised this book into three shorter publications.

Diesel Mechanics: Fundamentals is the first publication of a series of three texts dedicated to a diesel mechanics curriculum. Although it can be taught as a single text, it is hoped that it will be used in conjunction with *Diesel Mechanics: Fuel Systems* and *Diesel Mechanics: Electrical Systems* to provide continuity in student training. Other MAVCC publications entitled *Hydraulics* and *Power Trains* will broaden the scope of the diesel training. It is also hoped that the effort will provide industry with truly well trained technicians for the world of diesel and the varied skills it demands.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writers have numerous years of industry as well as teaching experience. Assisting them in their efforts were representatives of each of the member states who brought with them technical expertise and the experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and be accepted as a transportable basic teaching tool, organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committees that this publication will allow the students to become better prepared and more effective members of the work force.

Merle Rudebusch, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

PREFACE

Both the development and revision of instructional materials in diesel mechanics have been rewarding efforts because of the talented people who planned and wrote the materials. From the team of teachers, industry representatives, and trade and industrial staff members has come a series of texts which should offer diesel mechanics students an excellent opportunity for learning required skills.

The title of this introductory of the series, *Diesel Mechanics: Fundamentals* indicates that this book is dedicated to teaching the basic concepts related to employment in a diesel trade. Naturally, this book is designed to be used with other MAVCC books related to diesel. These include *Diesel Mechanics: Fuel Systems, Diesel Mechanics: Electrical Systems, Power Trains*, and *Hydraulics*.

As complex as some mechanical activities are, the MAVCC format presents the procedures in logically ordered objectives that facilitate a comfortable learning rate. The format also frees the instructor to concentrate on reinforcing classroom instruction with films, field trips, and other activities that serve to maintain student interest at a high level and motivate students to learn and do.

Despite careful planning and editing, we know that the text may perhaps contain a typographical error or two. Letting us know when you find such items will be a great help in improving the product before reprint time. But most of all, your input about the major elements in the book will be valuable help for changing or adding objectives when the materials are again revised and updated.

We respond to your suggestions, and we hope the quality of the materials in *Diesel Mechanics: Fundamentals* will serve a positive role in the classroom and provide industry with the skilled people that are so needed.

Ann Benson
Executive Director
Mid-America Vocational
Curriculum Consortium

ACKNOWLEDGEMENTS

Appreciation is extended to those individuals who contributed their time and talents to the development of *Diesel Mechanics: Fundamentals*.

The contents of this publication were planned and reviewed by:

Mid-America Vocational Curriculum Consortium Committee

Cliff Olson	Devils Lake, North Dakota
Dean Carter	Malvern, Arkansas
John Dagel	Watertown, South Dakota
Charles Cramton	West Wego, Louisiana
Ken Condor	Aurora, Colorado
Ted Modica	Albuquerque, New Mexico
Gary Snelson	Springfield, Missouri
David Goodacre	Drumright, Oklahoma
Jim Thompson	Beloit, Kansas
Bill August	Milford, Nebraska
Darwin Hutzell	Austin, Texas

Thanks are extended to Ron Simmons for representing teacher education on this committee and to Donnie Tuminello for representing state supervisory personnel.

Special thanks are extended to Harlan Gjoraas of the Kearns Machinery Company and Doug MacDonald of Technical Systems, Inc. for their representation of industry on the committee and to the numerous other companies who provided references and technical materials.

Gratitude is expressed to Jane Huston and P.J. Colbert for editing and to the Graphics Division of the Oklahoma State Department of Vocational and Technical Education for typing and art work.

The printing staff of the Oklahoma State Department of Vocational and Technical Education is deserving of much credit for printing this publication.

Special appreciation is extended to those who served on the original advisory committee representing the many MAVCC states.

USE OF THIS PUBLICATION

Instructional Units

Diesel Mechanics: Fundamentals includes 29 units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name
Label
List in writing
List orally
Letter
Record
Repeat
Give

Identify
Select
Mark
Point out
Pick out
Choose
Locate
Label

Describe
Define
Discuss in writing
Discuss orally
Interpret
Tell how
Tell what
Explain

Order
Arrange
Sequence
List in order
Classify
Divide
Isolate
Sort

Distinguish
Discriminate

Construct
Draw
Make
Build
Design
Formulate
Reproduce
Transcribe
Reduce
Increase
Figure

Demonstrate
Show your work
Show procedure
Perform an experiment
Perform the steps
Operate
Remove
Replace
Turn off/on
(Dis) assemble
(Dis) connect

Additional Terms Used
Evaluate
Complete
Analyze
Calculate
Estimate
Plan
Observe
Compare
Determine
Perform

Prepare
Make
Read
Tell
Teach
Converse
Lead
State
Write

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

DIESEL MECHANICS: FUNDAMENTALS

INSTRUCTIONAL/TASK ANALYSIS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

SECTION A--ORIENTATION
UNIT I: INTRODUCTION TO DIESEL

1. Inventors and their inventions
2. Occupational outlook
3. Places of employment
4. Student requirements
5. Steps in diesel shopwork
6. Diesel engine applications
7. Complete a personal information sheet

UNIT II: SHOP SAFETY

1. Terms and definitions
2. Safety color code
3. Personal safety rules
4. Shop safety rules
5. Sources of accidents
6. Classes of fires
7. Fire extinguishers
8. Complete safety pledge form
9. Complete individual student shop safety inspection

UNIT III: BASIC SHOP TOOLS

1. Basic shop tools
2. Use and maintenance
3. Micrometers

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

4. Read micrometer settings
5. Read vernier micrometer settings
6. Sharpen a twist drill
7. Drill holes with a drill press
8. Reshape a cold chisel
9. Cut flat metal with a cold chisel
10. Dress a grinding wheel
11. Regrind a screwdriver
12. Replace a hammer handle
13. Tin a soldering iron
14. Check a torque wrench for accuracy
15. Draw file a flat surface
16. Draw a twist drill to correct center
17. Use the outside micrometer
18. Use the vernier micrometer
19. Use the inside micrometer
20. Use the depth micrometer
21. Cut external threads
22. Cut internal threads

UNIT IV: TEST EQUIPMENT AND SERVICE TOOLS

1. Terms and definitions
2. Test equipment and service tools
3. Types of test tools
4. Types of service tools
5. Functions of test equipment
6. Functions of service tools

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

UNIT V: FASTENERS

1. Terms and definitions
2. Qualities of fasteners
3. Bolt head styles
4. SAE grade and metric bolts
5. Nuts
6. Washers
7. Tools for restoring threads
8. Snap rings

SECTION B--OPERATING PRINCIPLES

UNIT I: ENGINE OPERATING PRINCIPLES

1. Terms and definitions
2. Parts of a diesel engine
3. Operation of the diesel engine
4. Two stroke and four stroke engines
5. Calculate compression ratio
6. Calculate cubic inch displacement

UNIT II: DIESEL FUELS

1. Terms and definitions
2. Operating principles
3. Properties of diesel fuels
4. Characteristics of diesel fuels
5. Grades of diesel fuels
6. Causes of white and black smoke
7. Storing fuel

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

8. Protecting fuel quality

9. Measure specific gravity of diesel fuel

UNIT III: ENGINE LUBRICANTS

1. Terms and definitions
2. Functions of fuel oil
3. Characteristics of good engine oil
4. Oil ratings and classifications
5. SAE viscosity number
6. API classification system
7. Characteristics of good synthetic oil
8. Oil contaminants
9. Oil additives
10. Selection and use

UNIT IV: COOLANTS

1. Terms and definitions
2. Types of cooling systems
3. Parts of liquid cooling system
4. Parts of a marine cooling system
5. Parts of an air cooled engine
6. Advantages and disadvantages of water as a coolant
7. Antifreeze
8. Maintenance

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

UNIT V: BEARINGS

1. Terms and definitions
2. Functions and types of bearings
3. Load forces on bearings
4. Types of bearings
5. Construction of bearings
6. Distribution of lubricant to bearings
7. Causes of bearing failure
8. Reasons for bearing crush
9. Types of anti-friction bearings
10. Types of ball-bearing races
11. Designs of ball bearings
12. Types of roller bearings
13. Types of needle bearings
14. Mountings for anti-friction bearings
15. Maintenance
16. Remove and install a plain bearing
17. Remove and install an anti-friction bearing
18. Check preload bearing setting, spring scale method

UNIT VI: SEALS

1. Terms and definitions
2. Uses of seals
3. Types of seals
4. Locations of seals

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Dynamic seals
	6. Static seals
	7. Categories of sealants
8. Install a radial lip type seal	

SECTION C--ENGINE COMPONENTS

UNIT I: CYLINDER HEAD ASSEMBLY

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Parts of cylinder head assembly
	3. Forms of cylinder head castings
	4. Parts of valve assembly
	5. Types of valve rotators
	6. Valve arrangement
	7. Locations for turbulance chambers
	8. Forms of engine valves
9. Remove, inspect, and install a cylinder head	
10. Disassemble and service a valve train	
11. Service valve guides	
12. Service valve seats	
13. Service valve seat inserts	
14. Assemble a cylinder head	

UNIT II: PISTON AND CONNECTING ROD ASSEMBLIES

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Primary parts
	3. Functions of piston

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT II: PISTON AND CONNECTING ROD ASSEMBLIES

1. Terms and definitions
2. Primary parts
3. Functions of piston
4. Functions of piston rings
5. Types of piston rings
6. Types of ring joints
7. Causes of high oil consumption and blow-by
8. Types of piston pins
9. Construction of cap and of connecting rod
10. Markings
11. Remove piston and connecting rod assembly
12. Remove piston rings and piston from rod
13. Clean pistons
14. Inspect and measure pistons for wear
15. Install rings and assemble piston to rod
16. Inspect piston pin and connecting rod bushing for serviceability
17. Inspect and measure crankshaft for wear

UNIT III: CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING

1. Terms and definitions
2. Parts actuated by camshaft
3. Parts of camshaft
4. Parts in valve train
5. Valve timing

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

6. Gears found in gear train
7. Correct valve timing

8. Remove a camshaft
9. Remove camshaft gear
10. Service a camshaft
11. Install a camshaft
12. Adjust valve clearance on a valve-in-head engine
13. Remove camshaft on a Detroit diesel engine
14. Inspect camshaft on a Detroit diesel engine
15. Install camshaft on a Detroit diesel engine

UNIT IV: FRAMES AND CYLINDER BLOCKS

1. Terms and definitions
2. Stationary parts of typical frame designs
3. Purpose of through-bolts
4. Ways cylinder blocks may be constructed
5. Advantages of a removable liner over integral cylinder bore
6. Types of liners

7. Remove a cylinder liner
8. Install and inspect a cylinder liner

UNIT V: CRANKSHAFTS AND BEARINGS

1. Terms and definitions
2. Types of crankshaft construction
3. Parts of crankshaft
4. Effects of arrangement of crankshaft throws

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Ways crankshaft balance is maintained
	6. Lubrication
	7. Bushing and bearing differences
	8. Materials used in making bearing linings
	9. Types of bearing locks
	10. Bearing crush
	11. Purposes of oil grooves in the bearing
	12. Types of thrust bearings
	13. Engine indications of bearing failure
	14. Functions of flywheel
15. Remove a crankshaft	
16. Inspect and measure a crankshaft and bearings	
17. Install bearings and crankshaft	

SECTION D--AUXILIARY SYSTEMS
UNIT I: LUBRICATION SYSTEMS

1. Terms and definitions
2. Functions of lubrication systems
3. Types of lubrication systems
4. Components
5. Types of oil filters
6. Types of oil pumps
7. Sources of oil contamination
8. Purposes of lubricating valves
9. Oil coolers

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	10. Oil pressure indicating systems
11. Check and adjust oil pressure on a live engine	
12. Change an oil filter	

UNIT II: COOLING SYSTEMS

	1. Terms and definitions
	2. Functions of cooling system
	3. Effects of engine running hot or cold
	4. Parts in liquid cooling system
	5. Parts in air cooling system
	6. Types of radiators
	7. Functions of radiator cap
	8. Types of fans
	9. Types of fan control
	10. Types of temperature gauges
	11. Purposes for using coolant filter or conditioner in cooling system
	12. Functions of thermostat
	13. Types of thermostats
	14. Materials that may restrict radiator coolant flow
	15. Parts of water pump and fan
16. Reverse flush a radiator	
17. Test thermostat action	
18. Test for exhaust gas leakage and air in cooling system	

UNIT III: AIR INTAKE AND EXHAUST SYSTEMS

	1. Terms and definitions
	2. Parts of air intake system

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

3. Parts of exhaust system
4. Types of air cleaners
5. Port scavenging and valve scavenging
6. Positive displacement
7. Advantages of turbocharged engine

8. Test an engine for air flow restriction
9. Inspect a turbocharger for satisfactory operation
10. Remove, disassemble, service, assemble, and install a turbocharger
11. Disassemble a roots-type blower
12. Inspect a roots-type blower
13. Assemble a roots-type blower

UNIT IV: STARTING SYSTEMS

1. Terms and definitions
2. Types of starting systems
3. Compressed air admission
4. Components of starting systems
5. Low temperature starting aids

UNIT V: ENGINE BRAKES AND RETARDERS

1. Terms and definitions
2. Jacobs engine brake operation
3. Troubleshooting procedures
4. Brakesaver operation

5. Adjust a Jacobs engine brake on a Detroit diesel
6. Remove Brakesaver on a Caterpillar diesel engine

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
7. Disassemble a Brakesaver	
8. Assemble a Brakesaver	
9. Install a Brakesaver	
10. Install a Jacobs engine brake on a Mack diesel	
11. Adjust slave piston on a Jacobs engine brake on a Mack deisel	

SECTION E--ENGINE PERFORMANCE
UNIT I: OPERATION AND MAINTENANCE

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Duties of engine operator
	3. Inspections before starting and during operation
	4. Procedures for stopping diesel engine
	5. Performance records
	6. Possible engine malfunctions
	7. Engine knock
8. Complete a checklist before starting engine	
9. Complete a checklist during normal operation	
10. Complete a checklist before stopping engine	

UNIT II: DIAGNOSIS AND TESTING OF ENGINES

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Steps in diagnosing and testing an engine
	3. Checkpoints in inspecting and operating a diesel engine
	4. Tests made with dynamometer
	5. Factors necessary to produce horsepower
	6. Possible engine malfunctions

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
7. Complete a diesel troubleshooting guide	
8. Load test an engine with a dynamometer	
9. Test engine cylinder compression	
10. Check air intake system for restrictions	
11. Check crankcase pressure, exhaust back pressure, and air box pressure	

UNIT III: TUNE-UP AND ADJUSTMENT

	1. Terms and definitions
	2. Items to include in visual inspection checklist
3. Tune-up and service a diesel engine	
4. Tune-up a Cummins diesel engine	
5. Tune-up a Detroit diesel engine	
6. Tune-up a Caterpillar diesel engine	

UNIT IV: ENGINE STORAGE

	1. Terms and definitions
	2. Effects of climate on an engine in storage
	3. Systems that must be protected during permanent storage
4. Prepare an engine for temporary storage	
5. Prepare an engine for permanent storage	
6. Prepare a stored engine for service	

SECTION F--WELDING
UNIT I: ARC WELDING

	1. Terms and definitions
	2. Safety precautions
	3. Kinds of arc welders
	4. Equipment used

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Types of electrodes
	6. Sizes of electrodes used in arc welding
	7. Electrode classification system
	8. Purposes of electrode coating
	9. Selecting electrodes
	10. Methods of striking an arc
	11. Characteristics of arc length
	12. Parts of a drawing showing the welding processes
	13. Kinds of welds
	14. Types of weld joints
	15. Welding positions
	16. Poor welds
17. Start, stop, and restart a bead	
18. Construct a pad weld	
19. Construct a butt weld	
20. Make a pad in the vertical up position	
21. Make a pad in the overhead position	

UNIT II: OXYACETYLENE CUTTING

	1. Terms and definitions
	2. Parts of oxyacetylene cutting outfit
	3. Parts of a torch body and cutting attachment
	4. Rules for handling oxygen and acetylene equipment
	5. Types of oxyacetylene cutting flames
	6. Reasons for poor cuts

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	7. Causes of backfire
	8. Steps involved when backfire and flashback occur
9. Set up equipment for oxyacetylene cutting	
10. Turn on, light, and adjust to a neutral flame, and turn off oxyacetylene cutting equipment	
11. Make ninety-degree cuts on mild steel and restart a cut	
12. Cut round stock	

UNIT III: OXYACETYLENE FUSION WELDING

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Parts of equipment
	3. Factors that determine weld quality
	4. Properties of a good weld
	5. Factors that determine tip size
	6. Factors that determine type of filler rod
	7. Purpose of filler rod
	8. Types of oxyacetylene fusion welding flames
9. Turn on, light, adjust, and turn off oxyacetylene welding equipment	
10. Construct a corner weld without filler rod	
11. Lay beads on gauge metal without filler rod	
12. Lay beads on gauge metal with filler rod	
13. Weld butt joints with filler rod	

UNIT IV: OXYACETYLENE BRAZE WELDING

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Advantages and disadvantages of braze welding

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	3. Importance of having clean surface
	4. Methods for removing oxides from clean metal surface
	5. Purpose for using flux
	6. Molten bronze temperatures and reactions
7. Braze weld a square groove butt joint	

TOOLS AND EQUIPMENT

TOOL ROOM

1 Industrial puller set
1 Farm tractor puller set
1 1" Socket set (1 5/8"-3 1/2")
1 3/4" Socket set (7/8"-2 3/8")
1 1/2" Deep socket set (3/8"-7/8")
1 Allen set (1/8"-5/8")
1 Tap and die set NC
1 Tap and die set NF
1 Pipe tap set(1/8"-3/4")
1 Pilot reamer set (1/2"-1 1/4")
1 Cylinder hone, rigid
1 Universal sleeve puller set (less sleeve adapter plates)
1 Cylinder ridge reamer
1 Thread chaser
1 Electric drill (1/2")
2 Electric drills (1/4")
1 Set drill bits (1/16"-1/2")
1 Screw extractor set
1 Copper tubing service kit
1 Oil leakage detector
1 Oil leakage detector
1 Hydraulic jack (3-ton)
1 Hydraulic jack (20-ton)
1 Straight edge (4')
1 Volume grease dispenser
1 High pressure grease gun
1 Gear oil dispenser
1 Antifreeze tester
1 Battery hydrometer
4 Creepers (floor)
8 Light drop cords (25') (extension)
1 Sledge hammer
2 Cummins timing fixtures
4 Plastic hammers
4 Piston ring compressors
2 Hacksaws
1 Carburetor tool kit
1 Soldering gun kit
1 Carpenter square
1 Combination square
1 Set box end and open end wrenches (1/4"-2")
1 Set box end and open end wrenches (metric)
1 Set metric socket wrenches
1 Injector tube installation kit
1 Detroit blower service kit
1 Hydraulic flo-rater
1 Battery service kit
1 Bushing universal installation tool
6 Wire brushes
6 Carbon scrapers
1 Photo tachometer
1 Radiator pressure tester
1 Magnetic crack detector
1 Water pressure crack detector
1 Universal precup puller set
1 Adjustable wrench (20")
2 Torque wrenches (10-150 ft.-lb.)
1 Torque wrench (100-500 ft.-lb.)
1 Tin shears
2 Valve spring compressors
1 Micrometer set (0"-6") with standards and case
4 Micrometers (0-1")
4 Micrometers (1"-2")
4 Micrometers (2"-3")
2 Inside micrometer sets (2"-8")
2 Micrometer ball attachment
1 Universal dial test indicator set
1 Cylinder gauge (2 1/10"-6")
1 Micrometer depth gauge (0-6")
2 Oil measures (1 qt.)
2 Oil measures (1 gal.)
1 Pipe wrench (24")
1 Brake spring pliers
2 Battery carriers
2 Water buckets
2 Pairs, booster battery cables
2 Pry bars 23/32" x 24"
2 Rolling head bars 19/34" x 18"
10 Screwdrivers (assortment)
12 Files (assortment)
2 Compression testers
1 Leakage tester
2 Log chains (3/8" x 25')
1 Heli-coil kit
1 Stud remover 5/8"-1"
1 Copper tubing service kit (3/16"-5/8")
1 Feeler gauge set
Miscellaneous Supplies:
  Miscellaneous oil cans (hand)
  Gasket material
  Cotter pins (miscellaneous)
  Washers
  1 Fire extinguisher (20-lb.)

1 Flex stone set or glaze breaker
Miscellaneous drain pans and buckets

FUEL INJECTION EQUIPMENT TEST AND MOCK-UP SHOP

FUEL INJECTION TEST AREA

2 Steel benches and cabinet combination (30" x 6')
4 wall benches (24" x 36")
8 Wall fitting and adapter cabinets (5' x 4' x 1') glass fronts
4 Fuel injection test stands (miscellaneous fittings, adapters, and accessories)
1 Caterpillar fuel injection test stand (miscellaneous fittings, adapters, and special tools)
1 GM unit injector tester and accessories
1 Injector flow comparator
1 Diesel nozzle analyzer
1 Nozzle valve microscope
1 Nozzle valve lapping device and accessories
1 Ultrasonic cleaner
1 Nozzle high pressure cleaner
1 Torque vise
1 Concentricity gauge
2 Diesel nozzle testers
1 Set lapping blocks
1 Jar compound
2 Torque wrenches (5-600 inch-lbs.)
2 Torque wrenches (10-150 ft.-lbs.)
1 Compression tester
2 Fuel system analysis kit
8 Pump and nozzle (miscellaneous tool and service) kits
1 Universal dial test indicator set
1 Micrometer depth gauge (0"-6")
2 Micrometers (0"-1")
2 Micrometers (1"-2")
Miscellaneous items
Temperature and dust control equipment
Supplies (calibrating oil, cleaning solvent, and janitorial supplies)
Fuel injection mock-up shop
5 Steel benches and cabinet combination (30" x 6')
5 Vises (4")

30 Parts pans
1 Hand press (3-ton)
10 Steel racks (3. x 4., equipment)
1 small parts cleaner
1 Smokemeter (with stand)
6 Allen wrench sets (.028"-1/2")
7 Air hoses and fittings
Miscellaneous cutaway and demonstration equipment
Training mockup components

MAIN SHOP AREA

15 Steel benches (30" x 72")
15 Vises (4")
15 Parts racks (wood fabricated)
1 Portable floor jack (10-ton)
1 Portable floor jack (4-ton)
6 HD Engine stands
2 PTO Dynamometers
4 Chasis Dynamometers
1 Hydraulic press (75-ton)
1 Hand press (3-ton)
1 Clutch pressure plate adjusting fixture
1 10" Lathe and attachments
1 3/8" Drill press (bench)
1 3/4" Drill press (floor)
1 Connecting rod alignment fixture and adapters
2 Valve grinders
2 Valve seat grinders
1 Air compressor (3 h.p.)
Air hose and fittings
1 Small parts cleaner
1 Arc welder
1 Gas welding equipment (D.S.)
2 Pedestal grinders (10")
1 Mobile floor crane (4,000 lbs.)
1 Valve spring tester
Exhaust ventilating system
3 Fire extinguishers (20-lb.)

4 Farm tractor jack stands
Supplies (cleaning solutions and janitorial supplies)
Miscellaneous engines and tractors

BASIC ENGINE CLASSROOM SHOP COMBINATION

1 Blackboard and equipment
1 Instructor desk and chair
20 Classroom chairs (tablet arm)
1 Overhead projector
1 Film strip projector
17 Steel benches (30" x 6')
10 Vises (4")
1 Valve grinder
1 Valve seat grinder
1 Connecting rod aligner
1 Valve spring tester
1 Bench grinder (8")
1 Small parts washer
1 Battery charger
6 Batteries (12-volt)
12 Engines
12 Engines
Air hose and fittings
2 Torque wrenches (200 ft.-lbs.)
2 Torque wrenches (250 ft.-lbs.)
2 Piston ring compressors
2 Valve spring compressors
Miscellaneous small tools

DYNAMOMETER ROOM

Engine dynamometer (500 h.p.)
1 Engine dynamometer (700 h.p.)
2 Portable cooling columns
2 Engine stands (48" x 104")
1 Universal front engine mounts and adapter kit
1 Universal rear engine mounts and adapter kit
1 Engine cooling column interconnecting kit
1 Cooling column to engine adapter kit
2 Guard assemblies
8 Pedestals H.D.
2 Drive shafts H.D.
2 Farm tractor PTO drive shafts

BASIC ELECTRICAL CLASSROOM AND SHOP COMBINATION

1 Blackboard and equipment
1 Overhead projector
1 Film strip projector
1 Instructor desk and chair
15 Tables (30" x 6')
20 Chairs (swivel)
4 Steel racks (demonstration equipment)
12 Steel benches (30" x 6')
6 Generator test stands (drives)
2 Engines
2 Engine stands
3 Distributor testers
5 Volt-ampere testers
2 Battery starter testers
1 Battery tester
5 Vises (4")
1 Battery charger
1 Load bank
2 Armature testers
2 Ohmmeters
Miscellaneous jumper leads
6 Batteries (12-volt)
2 Generator field controls
4 Field rheostats
2 Pairs, battery booster cables
Miscellaneous tools
Electrical components (training)

STEAM AND HOT TANK ROOM

1 Steam cleaner
1 Hot tank and burner

BASIC HAND TOOL SET

1 tool box
1 Socket set, 1/4" square drive, composition:
  1 ratchet
  9 Sockets, 6 pt., (3/16" thru 1/2 m.)
  1 Flex t-handle
  1 Socket set, 3/8" square drive, composition:
  1 Ratchet
  7 Sockets, 12 pt. (3/8" thru 3/4")
  8 Sockets, deep well, 12 pt. (3/8" thru 13/16")
  3 Extension bars, (3", 6" and 10")
  2 Socket adapters, (3/8" to 1/4" and 3/8" and 3/8" to 1/2")
  3 Screwdriver bits, (.030, .039, .055)

- 1 Socket set, 1/2" square drive, composition
- 1 Ratchet
- 12 Sockets, 12 pt. (7/16" thru 1 1/2")
- 11 Deep sockets, 12 pt. (1/2" thru 1 1/8")
- 1 Spark plug socket (13/16")
- 1 Flex t-handle
- 1 Universal joint
- 3 Extension bars (3", 6", and 10")
- 1 Speeder (18")
- 1 Slide bar
- 1 Cross bar
- 2 Flex t-handles (15" and 18")
- 2 Socket adapters (1/2" to 3/8" and 1/2" to 3/4")

3 Wrench sets, composition
- 16 Combination wrenches (1/4" thru 1 1/8")
- 9 Open-end wrenches (1/4" x 5/16" thru 1 1/16" x 1 1/8")
- 11 Box-end wrenches (1/4" x 5/16" thru 1 1/16" x 1 1/4")
- 3 Flare nut wrenches (3/8 x 7/16 thru 5/8 x 11/16)

Miscellaneous tools
- 3 Phillips screwdrivers (Nos. 1, 2, and 3)
- 1 Offset screwdriver
- 4 Standard screwdrivers (3/16 x 4, 1/4 x 6, 5/16 x 8 and Stubby)
- 1 Line-up punch (12")
- 1 Punch and chisel set, 12 piece
- 6 Pliers, bent needle nose; battery pliers; diagonal/cutting pliers; slip joint pliers/ hose clamp pliers; locking pliers 10"
- 1 Hex key set, 11 pieces
- 1 Hacksaw with 10 extra blades
- 2 Hammers, ball peen (16 oz. and 40 oz.)
- 1 Hammer, (8-12 oz.) no-bounce, fiber tip
- 1 Rolling wedge bar (16")
- 1 Stainless steel rule
- 1 Gasket scraper
- 1 Ignition tile
- 2 Files, half-round (8" and 10")
- 1 File, round (6")
- 1 File, mil (10")
- 2 Feeler gauges, nonmagnetic (standard and long leaf)
- 1 Scratch awl
- 1 Flashlight (D size batteries)

REFERENCES

(NOTE: This is an alphabetized list of the publications used in completing this manual.)

ABC's of Fire Protection. Belleville, New Jersey: Walter Kidde and Company.

ABC's of Hand Tools. Detroit, Michigan: General Motors Corp.

Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A. *Modern Welding.* Homewood, Illinois: The Goodheart-Willcox Co., 1970.

An Accident Prevention Program for School Shops and Laboratories. Office of Education/ U.S. Department of Health, Education, and Welfare.

Billiet, Walter E., and Goings, Leslie F. *Automotive Electrical Systems.* 3rd ed. Chicago, Illinois: American Technical Society.

Crouse, William H. *Automotive Mechanics.* 7th ed. New York, New York: Webster Division/ McGraw-Hill Book Company, 1975.

Cummins Engine Company Shop Manual. Columbus, Indiana: Cummins Engine Co., Inc., 1974.

Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

Detroit Diesel Allison, Service Manual. Detroit, Michigan: General Motors Corp., 1973.

Detroit Diesel Engines: Service Manual. General Motors Corp., 1972.

Diesel Engineering Handbook. 12th ed. Stamford, Connecticut: Business Journals, Inc., 1972.

Engine Service Manual. Peoria, Illinois: Caterpillar Tractor Company, 1972.

Federal Register. Volume 37, Part II. Occupational Safety and Health Standards/ Department of Labor, 1972.

Forier, Louis C. *Motor Trucks and Diesel Repair Manual.* 33rd ed. New York: Motor, 1980.

Fundamentals of Service: Bearings and Seals. 3rd ed. Moline, Illinois: Deere and Co., 1980.

Fundamentals of Service: Electrical Systems. 4th ed. Moline, Illinois: Deere and Co., 1979.

Fundamentals of Service: Engines. 5th ed. Moline, Illinois: Deere and Co., 1980.

Fundamentals of Service: Fasteners. 2nd ed. Moline, Illinois: Deere and Co., 1979.

Fundamentals of Service: Fuels, Lubricants, and Coolants. 4th ed. Moline, Illinois: Deere and Co., 1980.

Fundamentals of Service: Shop Tools. 3rd ed. Moline, Illinois: Deere and Co., 1980.

Giachino, J. W.; Weeks, William; and Brune, Elmer. *Welding Skills and Practices.* 5th ed. Chicago: American Technical Society, 1977.

Hallenberg, A. H. *How to Teach Arc Welding in Farm Mechanics.* Cleveland, Ohio: James F. Lincoln Arc Welding Foundation.

H and NH Series Shop Manual. Columbus, Indiana: Cummins Engine Co., Inc.

Hobart Welding School Workbook. Troy, Ohio: Hobart Brothers' Technical Center.

Jefferson, T. B. *The Welding Encyclopedia.* 17th ed. Morton Grove, Illinois: Monticello Books, 1974.

Jones. M. M. *Shopwork on the Farm.* 2nd ed. New York: McGraw-Hill Book Co., Inc.

Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* 3rd ed. Chicago: American Techncial Society, 1974.

Kugler, Harold L. *Arc Welding Lessons for School and Farm Shop.* Cleveland, Ohio: James F. Lincoln Arc Welding Foundation.

New Lessons in Arc Welding. Cleveland, Ohio: The Lincoln Electric Co./James F. Lincoln Arc Welding Foundation.

Occupational Outlook Handbook. Bureau of Labor Statistics/Department of Labor, 1976.

OSHA Safety and Health Standards Digest. Occupational Safety and Health Administration/ U.S. Department of Labor, June 1975.

Parady, Harold W., and Turner, J. Howard. *Electric Energy.* Athens, Georgia: American Association for Vocational Instructional Materials, 1976.

Phipps, Lloyd J.; McColly, H. F.; Scranton, L. L.; and Cook, G. C. *Farm Mechanics Text and Handbook.* Danville, Illinois: Interstate Printers and Publishers, Inc.

Pierre, E. R. *Welding Processes and Power Sources.* 2nd ed. Minneapolis, Minnesota: Burgess Publishing Co., 1974.

Robert Bosch Corporation. Bulletin Number 221103. 4131-A Directors Row, Houston, Texas.

Roosa Master: Operation and Instructional Manual: Model DC Pump. Hartford, Connecticut: Stanadyne/Hartford Division/Roosa Master.

Safety Practices and Procedures in School Shops. New Jersey: Division of Vocational Education/Department of Education.

Service Bulletin No. 3379011-01: Injector Plunger and Valve Adjustments. Columbus, Indiana: Cummins Engine Co., December, 1975.

Service Bulletin No. 3379076-02: Cummins Engine Shop Manual. Columbus, Indiana: Cummins Engine Co., 1977.

Service Bulletin No. 3379101-00: PT Fuel Pump Calibration. Columbus, Indiana: Cummins Engine Co., December, 1975.

Service Bulletin No. 3379071-02: Injectors, All Types. Columbus, Indiana: Cummins Engine Co., December, 1975.

Service Bulletin No. 983725: Calibration of PT-G Pumps. Columbus, Indiana: Cummins Engine Co., 1975.

Service Bulletin No. 983535: Fuel Pump PT Rebuilding. Columbus, Indiana: Cummins Engine Co., 1975.

Service Manual: 3406 Industrial and Marine Engine. Caterpillar Tractor Company, 1979.

Shop Manual. Columbus, Indiana: Cummins Engine Co., 1974.

Smith's Short Course for Gas Cutting, Welding, Brazing. Minneapolis, Minnesota: Division of Tescom Corp./Education Department of Smith Welding Equipment.

Stockel, Martin W. *Auto Service and Repair.* Homewood, Illinois: Goodheart-Willcox Co., 1978.

Strong, Merle E. *Accident Prevention Manual.* American Technical Society, 1975.

The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures. New York: Linde Div./Union Carbide Corp.

Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Co., 1980.

V-71 Service Manual. Detroit, Michigan: Detroit Diesel Allison, Revised 1975.

INTRODUCTION TO DIESEL
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list facts concerning the occupational outlook for diesel mechanics and select places of employment. The student should also be able to list student requirements for entry into the diesel program and select steps involved in diesel shopwork. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match diesel engine inventors with their inventions.
2. List three facts concerning the occupational outlook for diesel mechanics.
3. Select places that employ diesel mechanics.
4. List student requirements for the diesel mechanics program.
5. Select steps involved in diesel shopwork.
6. List diesel engine applications.
7. Complete a personal information sheet.

INTRODUCTION TO DIESEL
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Show film.

Example: "ABC's of the Diesel Engine" (GM)

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency Master 1--Diesel Engine Applications
- D. Assignment Sheet #1--Complete a Personal Information Sheet
- E. Test
- F. Answers to test

II. References:

- A. *Occupational Outlook Handbook*. Bureau of Labor Statistics/Department of Labor, 1976.
- B. Kates, Edgar J. and Luck, William E. *Diesel and High Compression Gas Engines*. 3rd Edition. Chicago, Illinois: American Technical Society, 1972.
- C. *Diesel Engineering Handbook*. 12th Edition. Stamford, Connecticut: Business Journals, Inc., 1972.
- D. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

INTRODUCTION TO DIESEL
UNIT I

INFORMATION SHEET

I. History of the diesel engine

   A. 1794--Street invented first internal combustion engine

   B. 1824--Sadi Carnot, French engineer, formulated the following ideas which were used in internal combustion engines:

      1. Self-ignition of fuel in highly compressed air

         (NOTE: Fuel is already mixed with air.)

      2. Compression of the air before ignition

         (NOTE: Fuel is introduced after compression of air.)

      3. Means of cylinder cooling

      4. The use of exhaust heat for boilers

   C. 1860--Lenoir produced the first commercial internal combustion engine

   D. 1862--Beau DeRochas invented 4 stroke cycle of operation

   E. 1867--Otto built first free piston engine

   F. 1881--Clerk built the first 2 cycle engine

   G. 1890--Ackroyd-Stuart started the first compression ignition engine; this engine was patented and had a pre-combustion chamber

   H. 1892--Dr. Rudolf Diesel credited with developing the diesel engine; his third engine, built in 1895, ran on fuel oil and had 35% thermal efficiency

II. Occupational outlook

   A. Job opportunities result each year from the need to replace experienced mechanics who are promoted, retired, or transferred to related fields of work

   B. Number of diesel engine applications increases each year requiring more mechanics to service them

   C. Demand for diesel power has increased due to the added economy, endurance, and efficiency of the diesel engine as compared to other power units

INFORMATION SHEET

III. Places of employment for diesel mechanics

   A. Independent repair shops

   B. Service departments of dealers and distributors

   C. Sales agencies and manufacturers of diesel engines

   D. Truck leasing companies

   E. Federal, state, and local government vehicle maintenance depots

   F. Electric power plants

   G. Railroad locomotive shops

   H. Fuel injection repair station

   I. Marine

   J. Oil fields

   K. Mining

   L. Agriculture

   M. Heavy equipment

IV. Student requirements for the diesel mechanics program

   A. Operate the shop equipment correctly

   B. Be safety conscious; follow safety regulations

   C. Take instructions readily; follow directions

   D. Be a good citizen

   E. Control temper

   F. Have enthusiasm about work

   G. Have pride in the trade and workmanship

   H. Be conscious of waste in materials and man-hours

   I. Be punctual

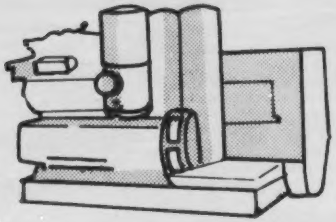
INFORMATION SHEET

V. Steps involved in diesel shopwork
  A. Troubleshooting
  B. Disassembly
  C. Measuring
  D. Metal work or machining
  E. Installing new parts
  F. Reassembly
  G. Adjustments and testing

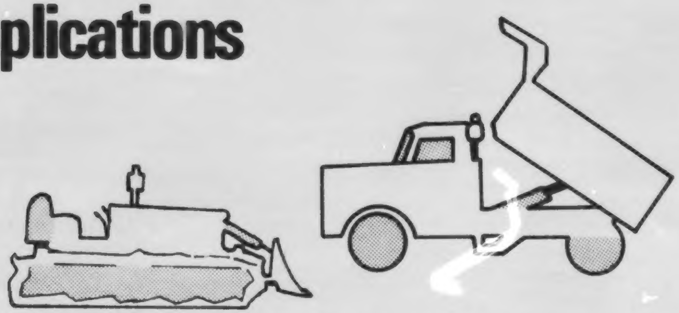
VI. Diesel engine applications (Transparency 1)
  A. Electric power plants
  B. Marine engines
  C. Farm tractors and equipment
  D. Road building equipment
  E. Automotive vehicles

     (NOTE: These vehicles include trucks, buses, and automobiles.)
  F. Rail locomotives
  G. Construction equipment

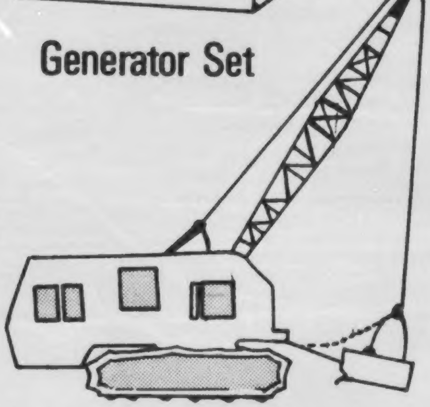
Diesel Engine Applications



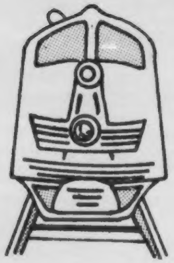
Generator Set



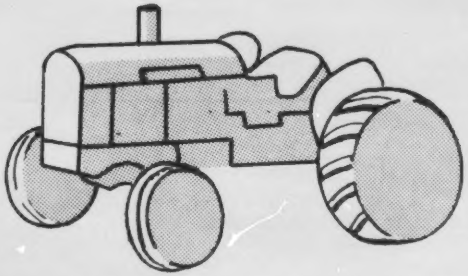
Road Building Equipment



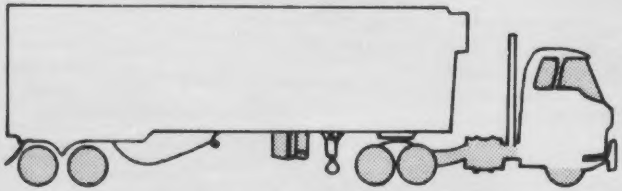
Construction Equipment



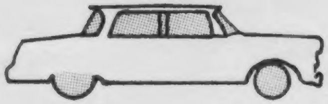
Rail Locomotives



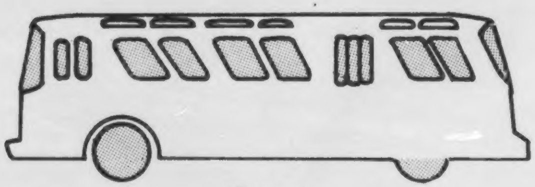
Farm Tractors and Equipment



Trucks



Cars



Buses

Automotive Vehicles

INTRODUCTION TO DIESEL
UNIT I

ASSIGNMENT SHEET #1--COMPLETE A PERSONAL INFORMATION SHEET

Directions: Complete the following personal data and turn in to the instructor.

NAME: ____________________

HOME SCHOOL: ____________________

AGE: ____________________

BIRTH DATE: ____________________

GRADE CLASSIFICATION: ____________________

OCCUPATIONAL OBJECTIVE: ____________________

____

SOCIAL SECURITY NUMBER: ____________________

PARENTS' NAMES: ____________________

PARENTS' OCCUPATIONS: ____________________

EMERGENCY TELEPHONE NUMBER: ____________________

INTRODUCTION TO DIESEL
UNIT I

NAME ______________________

TEST

1. Match diesel engine inventors on the right with their inventions.

______ a. 1794--Invented first internal combustion engine

______ b. 1824--Formulated the following ideas which were used in internal combustion engines:

   1) Self-ignition of fuel in highly compressed air
   2) Compression of the air before ignition
   3) Means of cylinder cooling
   4) The use of exhaust heat for boilers

______ c. 1860--Produced the first commercial internal combustion engine

______ d. 1862--Invented 4 stroke cycle of operation

______ e. 1867--Built first free piston engine

______ f. 1881--Built the first 2 cycle engine

______ g. 1890--Started the first compression ignition engine; this engine was patented and had a pre-combustion chamber

______ h. 1892--Credited with developing the diesel engine; his third engine, built in 1895, ran on fuel oil and had 35% thermal efficiency

1. Otto
2. Sadi Carnot
3. Lenoir
4. Dr. Rudolf Diesel
5. Clerk
6. Street
7. Beau De Rochas
8. Ackroyd-Stuart

2. List three facts concerning the occupational outlook for diesel mechanics.

a. ____

b. ____

c. ____

3. Select the places that employ diesel mechanics by placing an "X" in the appropriate blanks.

_____a. Sales agencies and manufacturers of diesel engines

_____b. Motorcycle sales agencies

_____c. Lawnmower repair shop

_____d. Independent repair shops

_____e. Electric power plants

_____f. Service departments of dealers and distributors

_____g. Railroad locomotive shops

_____h. Fuel injection repair station

_____i. Oil fields

_____j. Agriculture

4. List six student requirements for the diesel mechanics program.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

5. Select the steps involved in diesel shopwork by placing an "X" in the appropriate blanks.

_____a. Repair estimating

_____b. Disassembly

_____c. Metal work or machining

_____d. Measuring

_____e. Reassembly

_____f. Sales

_____g. Installing new parts

_____h. Adjustments and testing

_____i. Troubleshooting

6. List five diesel engine applications.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

7. Complete a personal information sheet.

   (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

INTRODUCTION TO DIESEL
UNIT I

ANSWERS TO TEST

1. a. 6
   b. 2
   c. 3
   d. 7
   e. 1
   f. 5
   g. 8
   h. 4

2. a. Job opportunities result each year from the need to replace experienced mechanics who are promoted, retired, or transferred to related fields of work

   b. Number of diesel engine applications increases each year requiring more mechanics to service them

   c. Demand for diesel power has increased due to the added economy, endurance, and efficiency of the diesel engine as compared to other power units

3. a, d, e, f, g, h, i, j

4. Any six of the following:

   a. Operate the shop equipment correctly
   b. Be safety conscious; follow safety regulations
   c. Take instructions readily; follow directions
   d. Be a good citizen
   e. Control temper
   f. Have enthusiasm about work
   g. Have pride in the trade and workmanship
   h. Be conscious of waste in materials and man-hours
   i. Be punctual

5. b, c, d, e, g, h, i

6. Any five of the following:

   a. Electric power plants
   b. Marine engines
   c. Farm tractors and equipment
   d. Road building equipment
   e. Automotive vehicles
   f. Rail locomotives
   g. Construction equipment

7. Evaluated to the satisfaction of the instructor

SHOP SAFETY
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to recognize unsafe situations, list general shop and personal safety rules, and select the correct fire extinguisher for use in case of fire. The student should also be able to recognize the uses of the safety color code, complete a safety pledge form, and complete an individual shop safety inspection. This knowledge will be evidenced by correctly performing the procedures in the assignment sheets and by scoring 100 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with shop safety with the correct definitions.
2. Match the colors of the safety color code with the correct applications.
3. List personal safety rules.
4. List general shop safety rules.
5. Match possible sources of accidents with the injury which may occur.
6. Match the four classes of fire with the correct statements defining each class.
7. Match the type or types of fire extinguishers with the class of fire they are used on.
8. Complete safety pledge form.
9. Complete individual student shop safety inspection.

SHOP SAFETY
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate the use of fire extinguishers.

VII. Take students on tour of shop prior to completion of Assignment Sheet #2.

VIII. Have speaker from the local fire department demonstrate the use of fire extinguishers.

IX. Show safety films.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency Master 1--Types of Fire Extinguishers
- D. Assignment sheets
  - 1. Assignment Sheet #1--Complete Safety Pledge Form
  - 2. Assignment Sheet #2--Complete Individual Student Shop Safety Inspection
- E. Test
- F. Answers to test

II. References:

- A. *The ABC's of Fire Protection.* Belleville, New Jersey: Walter Kidde and Company.

B. *An Accident Prevention Program for School Shops and Laboratories*. Office of Education/U.S. Department of Health, Education, and Welfare.

C. *Safety Practices and Procedures in School Shops*. New Jersey: Division of Vocational Education/Department of Education.

D. Strong, Merle E. *Accident Prevention Manual*. American Technical Society, 1975.

E. *OSHA Safety and Health Standards Digest*. Occupational Safety and Health Administration/U.S. Department of Labor, June 1975.

F. *Federal Register*. Volume 37, Part II. Occupational Safety and Health Standards/Department of Labor, 1972.

G. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

SHOP SAFETY
UNIT II

INFORMATION SHEET

I. Terms and definitions

  A. Safety--State or condition of being free from danger, risk, or injury

  B. Accident--Any suddenly occurring, unintentional event which causes injury or property damage

  C. First aid--Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

  D. Liability--Legal responsibility which binds an individual in law and justice to do something which may be enforced by action

II. Colors and applications of the safety color code

  A. Green--Designates "Safety" and the location of first aid equipment

  B. Yellow--Designates caution and marks physical hazards

  C. Orange--Designates dangerous parts of equipment which may cut, crush, shock, or otherwise injure

  D. Red--Used to identify the location of fire fighting equipment and apparatus

  (NOTE: Emergency fire exits shall be designated in red. Buttons or levers for electrical switches used for the stopping of machinery should be designated in red. Gasoline cans should be painted red with additional identification in the form of a yellow band around the can.)

  E. Blue--Designates caution against starting equipment while it is being worked upon, or against the use of defective equipment

  (NOTE: A blue tag should be lettered "Out of Order.")

  F. Black, white, or combinations of black and white--Designates traffic and housekeeping markings

  G. Purple--Designates radioactive material

III. Personal safety rules

  A. Wear shop clothing and work shoes appropriate to the activity being performed

  B. Confine long hair at all times

  C. Always wear eye protection when using grinding wheels, rotating brushes, and as required

INFORMATION SHEET

D. Remove ties when working around machine tools or rotating equipment

E. Remove rings and other jewelry when working in the shop

F. Conduct yourself in a manner conducive to safe shop practices

G. Keep mentally alert to shop hazards

IV. General shop safety rules

A. Keep all hand tools clean and in safe working order

B. Report any defective tools, machines, or other equipment to the instructor

Example: A loose hammer head is a defective tool

C. Retain all guards and safety devices except with the specific authorization of the instructor

D. Operate powered equipment only after receiving instruction on how to operate the machine safely

E. Report all accidents to the instructor regardless of nature or severity

F. Turn off the power before leaving a machine tool

G. Make sure all guards and barriers are in place and adjusted properly before starting a machine tool

H. Disconnect the power from machine tools before performing any maintenance task

I. Use a solvent only after determining its properties, what kind of work it has to do, and how to use it

J. Use correct and proper size wrenches for nuts, bolts, and objects to be turned or held

K. Keep the shop or laboratory floor clear of tools, scraps, and litter

L. Clean up any spilled liquids immediately

M. Store oily rags or oily waste in metal containers

N. Clean the chips from a machine with a brush; do not use a rag or bare hands

O. Use proper support for all heavy objects

P. Practice tool motto: "Get, use, and put away"

INFORMATION SHEET

V. Sources of accidents and injuries which may occur

   A. Horseplay–May cause person or persons to fall against sharp objects or moving machinery

   B. Air hose--One blast may rip clothing or skin

   C. Grinder--May cause eye injury from flying sparks or metal chips

   D. Batteries--May explode when near open flame or electrical spark

   E. Moving parts--May catch fingers or clothing

   F. Loose clothing--May catch in rotating parts

   G. Tools--Sharp edges may puncture skin

   H. Electric power tools--May cause shock if not grounded

   I. Lack of or improper supporting device under heavy objects--A fall may cause a fatal injury

   J. Lifting heavy objects--May cause severe back injury

VI. Classes of fires

   A. Class A--Fires that occur in ordinary combustible materials

   Examples: Wood, rags, and rubbish

   B. Class B--Fires that occur with flammable liquids

   Examples: Gasoline, oil, grease, paints, and thinners

   C. Class C--Fires that occur in or near electrical equipment

   Examples: Motors, switchboards, and electrical wiring

   D. Class D--Fires that occur in combustible metals

   Examples: Magnesium, titanium, zirconium, lithium, and sodium potassium

VII. Types of fire extinguishers (Transparency 1)

   A. Pressurized water--Used for Class A fires

   (NOTE: The pressurized water extinguisher usually operates by squeezing a handle or trigger.)

INFORMATION SHEET

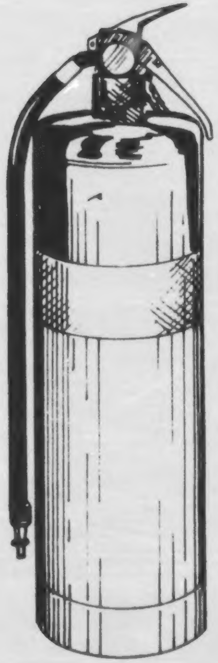
B. Dry chemical--Used on Class B and C fires

(NOTE: The dry chemical extinguisher usually operates by squeezing a handle, trigger, or lever.)

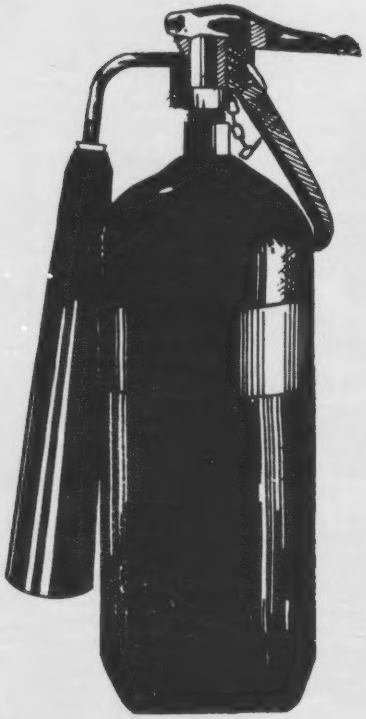
C. Carbon dioxide (CO_2)--Used on Class B and C fires

(NOTE: The carbon dioxide (CO_2) extinguisher usually operates by squeezing a handle or trigger.)

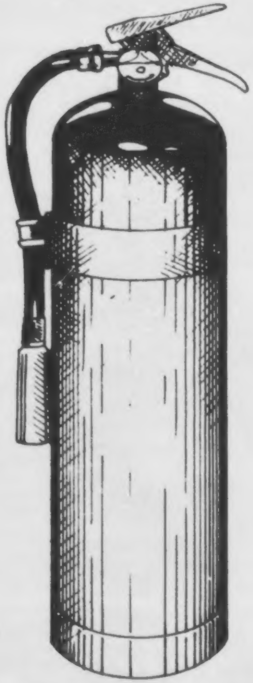
Types of Fire Extinguishers



Pressurized Water
for Class A Fires



Carbon Dioxide for
Class B and C Fires



Dry Chemical for
Class B and C Fires

SHOP SAFETY
UNIT II

ASSIGNMENT SHEET #1--COMPLETE SAFETY PLEDGE FORM

Directions: Read and complete the student safety pledge form by filling in the blanks. Return form to instructor no later than ____________________________.

STUDENT SAFETY PLEDGE FORM

________________ ________________ ________________, who is enrolled in Vocational

______________ ______________, will as a part of the shop experience, operate machines,

providing that the parent or guardian gives written permission.

It is understood that each student will be given proper instruction, both in the use of the equipment and in correct safety procedures concerning it, before being allowed to operate the machines. The student must assume responsibility for following safe practices; therefore, we ask that the student subscribe to the following safety pledge.

1. I PROMISE TO FOLLOW ALL SAFETY RULES FOR THE SHOP.
2. I PROMISE NEVER TO USE A MACHINE WITHOUT FIRST HAVING PERMISSION FROM THE INSTRUCTOR.
3. I WILL NOT ASK PERMISSION TO USE A PARTICULAR MACHINE UNLESS I HAVE BEEN INSTRUCTED IN ITS USE, AND HAVE MADE 100% ON THE SAFETY TEST FOR THAT MACHINE.
4. I WILL REPORT ANY ACCIDENT OR INJURY TO THE INSTRUCTOR IMMEDIATELY.

DATE ___________ STUDENT'S SIGNATURE ___________________________

I hereby give my consent to allow my son or daughter to operate all machines and equipment necessary in carrying out the requirements of the course in which he/she is enrolled.

DATE ___________ PARENT'S SIGNATURE ____________________________
(If required)

Parents are cordially invited to visit the shop to inspect the machines and to see them in operation.

SHOP SAFETY
UNIT II

ASSIGNMENT SHEET #2--COMPLETE INDIVIDUAL STUDENT SHOP SAFETY INSPECTION

Directions: Complete the safety inspection checklist by physically conducting an inspection of the shop area.

CHECKING PROCEDURE

Draw a circle around the appropriate letter, using the following letter scheme:

S -- Satisfactory (needs no attention)
A -- Acceptable (needs some attention)
U -- Unsatisfactory (needs immediate attention)

Recommendations should be made in all cases where a "U" is circled. Space is provided at the end of the form for such comments.

A. GENERAL PHYSICAL CONDITION

1. Machines, benches, and other equipment are arranged to conform to good safety practices S A U
2. Condition of stairways and ramps S A U
3. Condition of aisles S A U
4. Condition of floors S A U
5. Condition of walls, windows, and ceiling S A U
6. Illumination is safe, sufficient, and well placed S A U
7. Ventilation is adequate and proper for conditions S A U
8. Temperature control S A U
9. Fire extinguishers are of proper type, adequately supplied, properly located, and maintained S A U
10. Teacher and pupils know location of and how to use proper type for various fires S A U
11. Number and location of exits is adequate and properly identified S A U

ASSIGNMENT SHEET #2

12. Walls are clear of objects that might fall S A U
13. Utility lines are properly identified S A U
14. Air in shop is free from excessive dust and smoke S A U
15. Evaluation for the total rating of GENERAL PHYSICAL CONDITION S A U

B. HOUSEKEEPING

1. General appearance as to orderliness S A U
2. Adequate and proper storage space for tools and materials S A U
3. Benches are kept orderly S A U
4. Corners are clean and clear S A U
5. Special tool racks, in orderly condition, are provided at benches and machines S A U
6. Tool, supply, and/or material room is orderly S A U
7. Sufficient scrap boxes are provided S A U
8. Scrap stock is put in scrap boxes promptly S A U
9. Materials are stored in an orderly and safe condition S A U
10. A spring lid metal container is provided for waste and oily rags S A U
11. Dangerous materials are stored in metal cabinets S A U
12. Machines have been color conditioned S A U
13. Safety cans are provided for flammable liquids S A U
14. Floors are free of oil, water, and foreign material S A U
15. Evaluation for the total rating for HOUSEKEEPING S A U

ASSIGNMENT SHEET #2

C. EQUIPMENT

1. Machines are arranged so that workers are protected from hazards of other machines and passing students S A U
2. Danger zones are properly indicated and guarded S A U
3. All gears and moving belts are protected by permanent enclosure guards S A U
4. All equipment control switches are easily available to operator S A U
5. Nonskid areas are provided around machines S A U
6. Tools are kept sharp, clean, and in safe working order S A U
7. Evaluation for the total rating for EQUIPMENT S A U

D. ELECTRICAL INSTALLATION

1. All switches are enclosed S A U
2. There is a master control switch for all of the electrical installations S A U
3. All electrical extension cords are in safe condition and are not carrying excessive loads S A U
4. All machine switches are within easy reach of the operators S A U
5. Individual cut-off switches are provided for each machine S A U
6. No temporary wiring in evidence S A U
7. Evaluation for the total rating for ELECTRICAL INSTALLATION S A U

ASSIGNMENT SHEET #2

E. PERSONAL PROTECTION (Read only)

1. Goggles or protective shields are provided and required for all work where eye hazards exist
2. If individual goggles are not provided, hoods and goggles are properly disinfected before use
3. Shields and goggles are provided for electric welding
4. Rings and other jewelry are removed by pupils when working in the shop
5. Proper kind of wearing apparel is worn and worn properly for the job being done
6. Leggings and safety shoes are worn in special classes
7. Respirators are provided for dusty or toxic atmospheric conditions such as when spraying in the finishing room
8. Provisions are made for cleaning and sterilizing respirators
9. Students are examined for safety knowledge ability
10. Sleeves are rolled above elbows when operating machines
11. Clothing of students is free from loose sleeves, flopping ties, and loose coats

RECOMMENDATIONS

SHOP SAFETY
UNIT II

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Legal responsibility which binds an individual in law and justice to do something which may be enforced by action

______b. Any suddenly occurring, unintentional event which causes injury or property damage

______c. State or condition of being free from danger, risk, or injury

______d. Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

1. Safety
2. First aid
3. Liability
4. Accident

2. Match the colors of the safety color code on the right with the correct applications.

______a. Designates caution and marks physical hazards

______b. Used to identify the location of fire fighting equipment and apparatus

______c. Designates "Safety" and the location of first aid equipment

______d. Designates dangerous parts of equipment which may cut, crush, shock, or otherwise injure

______e. Designates caution against starting equipment while it is being worked upon, or against the use of defective equipment

______f. Designates traffic and housekeeping markings

______g. Designates radioactive material

1. Green
2. Black, white, or combinations of black and white
3. Orange
4. Blue
5. Red
6. Yellow
7. Purple

3. List five personal safety rules.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

4. List eight general shop safety rules.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

   h. ______________________________

5. Match possible sources of accidents on the right with the injury which may occur.

______a. May cause person or persons to fall against sharp objects or moving machinery

______b. One blast may rip clothing or skin

______c. May cause eye injury from flying sparks or metal chips

______d. May explode when near open flame or electrical spark

______e. May catch fingers or clothing

______f. May catch in rotating parts

______g. Sharp edges may puncture skin

______h. May cause shock if not grounded

______i. A fall may cause a fatal injury

______j. May cause severe back injury

1. Horseplay
2. Grinder
3. Batteries
4. Air hose
5. Moving parts
6. Loose clothing
7. Electric power tools
8. Tools
9. Lack of or improper supporting device under heavy objects
10. Lifting heavy objects

6. Match the four classes of fire on the right with the correct statements defining each class.

   _____a. Fires that occur in ordinary combustible materials

   _____b. Fires that occur with flammable liquids

   _____c. Fires that occur in or near electrical equipment

   _____d. Fires that occur in combustible metals

   1. Class B
   2. Class A
   3. Class C
   4. Class D

7. Match the type or types of fire extinguishers on the right with the class of fire they are used on.

   _____a. Class A

   _____b. Class B

   _____c. Class C

   1. Pressurized water
   2. Carbon dioxide (CO_2)
   3. Dry chemical

8. Complete safety pledge form.

9. Complete individual student shop safety inspection.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SHOP SAFETY
UNIT II

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 1
   d. 2

2. a. 6
   b. 5
   c. 1
   d. 3
   e. 4
   f. 2
   g. 7

3. Any five of the following:

   a. Wear shop clothing and work shoes appropriate to the activity being performed
   b. Confine long hair at all times
   c. Always wear eye protection when using grinding wheels, rotating brushes, and as required
   d. Remove ties when working around machine tools or rotating equipment
   e. Remove rings and other jewelry when working in the shop
   f. Conduct yourself in a manner conducive to safe shop practices
   g. Keep mentally alert to shop hazards

4. Any eight of the following:

   a. Keep all hand tools clean and in safe working order
   b. Report any defective tools, machines, or other equipment to the instructor
   c. Retain all guards and safety devices except with the specific authorization of the instructor
   d. Operate powered equipment only after receiving instruction on how to operate the machine safely
   e. Report all accidents to the instructor regardless of nature or severity
   f. Turn off the power before leaving a machine tool
   g. Make sure all guards and barriers are in place and adjusted properly before starting a machine tool
   h. Disconnect the power from machine tools before performing any maintenance task
   i. Use a solvent only after determining its properties, what kind of work it has to do, and how to use it
   j. Use correct and proper size wrenches for nuts, bolts, and objects to be turned or held
   k. Keep the shop or laboratory floor clear of tools, scraps, and litter
   l. Clean up any spilled liquids immediately
   m. Store oily rags or oily waste in metal containers
   n. Clean the chips from a machine with a brush; do not use a rag or bare hands
   o. Use proper support for all heavy objects
   p. Practice tool motto: "Get, use, and put away"

5. a. 1
   b. 4
   c. 2
   d. 3
   e. 5
   f. 6
   g. 8
   h. 7
   i. 9
   j. 10

6. a. 2
   b. 1
   c. 3
   d. 4

7. a. 1
   b. 2, 3
   c. 2, 3

8. Evaluated to the satisfaction of the instructor

9. Evaluated to the satisfaction of the instructor

BASIC SHOP TOOLS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify and choose the right tool for the job and maintain them in a safe condition. The student should also be able to repair and sharpen certain tools and be able to accurately read measuring instruments. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Identify basic shop tools.
2. Identify types of screwdrivers.
3. Name two types of hammers.
4. Identify types of pliers.
5. Identify types of wrenches.
6. Identify types of cold chisels.
7. Identify types of punches.
8. Identify types of file teeth.
9. Name precautions for correct use of the hacksaw.
10. Name three principal parts of a twist drill.
11. Name three ways to extract a screw.
12. Identify three types of pullers.
13. Name three shop tools used for measuring speed.
14. List two types of feeler gauges.
15. Name three types of taps and their functions.
16. Distinguish between correct and incorrect methods of using and maintaining basic shop tools.
17. Name four types of micrometers.

18. Read the micrometer settings.

19. Read the vernier micrometer settings.

20. Demonstrate the ability to:

    a. Sharpen a twist drill.

    b. Drill holes with a drill press.

    c. Reshape a cold chisel.

    d. Cut flat metal with a cold chisel.

    e. Dress a grinding wheel.

    f. Regrind a screwdriver.

    g. Replace a hammer handle.

    h. Tin a soldering iron.

    i. Check a torque wrench for accuracy.

    j. Draw file a flat surface.

    k. Draw a twist drill to correct center.

    l. Use the outside micrometer.

    m. Use the vernier micrometer.

    n. Use the inside micrometer.

    o. Use the depth micrometer.

    p. Cut external threads.

    q. Cut internal threads.

BASIC SHOP TOOLS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Have students make a list of beginning tools.

VIII. Have students make a list of special tools.

IX. Show film on tool safety.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Basic Shop Tools
    2. TM 2--Basic Shop Tools (Continued)
    3. TM 3--Basic Shop Tools (Continued)
    4. TM 4--Types of Screwdrivers
    5. TM 5--Types of Pliers
    6. TM 6--Types of Wrenches
    7. TM 7--Types of Wrenches (Continued)
    8. TM 8--Types of Wrenches (Continued)
    9. TM 9--Types of Cold Chisels
    10. TM 10--Types of Punches

11. TM 11--Types of Files
12. TM 12--Types of Pullers
13. TM 13--Types of Taps
14. TM 14--Right and Wrong Use of Tools
15. TM 15--Right and Wrong Use of Tools (Continued)
16. TM 16--Right and Wrong Use of Tools (Continued)
17. TM 17--Right and Wrong Use of Tools (Continued)
18. TM 18--Types of Micrometers
19. TM 19--Reading a Micrometer
20. TM 20--Sleeve Readings

    Overlay 20A--Thimble Sleeve Readings
21. TM 21--Vernier Micrometer Readings

    Overlay 21A--Vernier Sleeve Readings

D. Assignment sheets

1. Assignment Sheet #1--Read the Micrometer Settings
2. Assignment Sheet #2--Read the Vernier Micrometer Settings

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Sharpen a Twist Drill
2. Job Sheet #2--Drill Holes with a Drill Press
3. Job Sheet #3--Reshape a Cold Chisel
4. Job Sheet #4--Cut Flat Metal with a Cold Chisel
5. Job Sheet #5--Dress a Grinding Wheel
6. Job Sheet #6--Regrind a Screwdriver
7. Job Sheet #7--Replace a Hammer Handle
8. Job Sheet #8--Tin a Soldering Iron
9. Job Sheet #9--Check a Torque Wrench for Accuracy
10. Job Sheet #10--Draw File a Flat Surface
11. Job Sheet #11--Draw a Twist Drill to Correct Center
12. Job Sheet #12--Use the Outside Micrometer

13. Job Sheet #13--Use the Vernier Micrometer
14. Job Sheet #14--Use the Inside Micrometer
15. Job Sheet #15--Use the Depth Micrometer
16. Job Sheet #16--Cut External Threads
17. Job Sheet #17--Cut Internal Threads

G. Test

H. Answers to test

II. References:

A. *Fundamentals of Service: Shop Tools*. 3rd ed. Moline, Illinois: Deere and Company, 1980

B. *ABC's of Hand Tools*. Detroit, Michigan: General Motors Corporation, General Motors Building, 1945.

C. Dagel, John F. *Diesel Engine Repairs*. New York: John Wiley and Sons, Inc., 1982.

BASIC SHOP TOOLS
UNIT III

INFORMATION SHEET

I. Basic shop tools (Transparencies 1, 2, and 3)

   A. Common screwdriver

   B. Ball peen hammer

   C. Slip joint pliers

   D. Combination box and open-end wrench

   E. Flat cold chisel

   F. Center punch

   G. Flat file

   H. Hacksaw

   I. Vise

   J. "C" clamp

   K. Twist drill

   L. Screw extractor

   M. External puller

   N. Magnetic pick-up tool

   O. Tubing cutter

   P. Soldering iron

   Q. Feeler gauge

   R. Outside micrometer

   S. Dial indicator

   T. Spring tester

   U. Pressure gauge (oil pressure)

   V. Tachometer

INFORMATION SHEET

II. Types of screwdrivers (Transparency 4)

  A. Common

  B. Phillips head

  C. Clutch head

  D. Starting

  E. Offset

III. Types of hammers

  A. Ball peen

  B. Soft

  (NOTE: Types of soft hammers are lead, rawhide, plastic, brass, and rubber.)

IV. Types of pliers (Transparency 5)

  A. Slip joint

  B. Diagonal cutters

  C. Needle nose

  D. Side cutters

  E. Lock grip

  F. Snap ring

V. Types of wrenches (Transparencies 6, 7, and 8)

  A. Open end

  B. Adjustable

  C. Box

  D. Tubing

  E. Hook spanner

  F. Adjustable hook spanner

INFORMATION SHEET

G. Socket
  1. Sliding "T" handle
  2. Extension
  3. Ratchet handle
  4. Speed handle
  5. Universal joint

  (NOTE: The sockets may be six point, twelve point, or deepwell.)

H. Torque

I. Allen

J. Pipe

K. Striking

VI. Types of cold chisels (Transparency 9)

A. Flat

B. Cape

C. Round nose

D. Diamond point

VII. Types of punches (Transparency 10)

A. Starting

B. Pin

C. Center

D. Aligning

VIII. Types of file teeth (Transparency 11)

A. Single cut

B. Double cut

C. Rasp cut

D. Curved tooth

(NOTE: Files are made in numerous sizes and shapes. Common shapes are round, half round, flat, and triangle.)

INFORMATION SHEET

IX. Precautions for correct use of hacksaw

  A. Teeth must point away from handle

  B. Blade must be tightly stretched

  C. Select blade with correct number of teeth per inch for material being cut (NOTE: Two teeth should always be contacting the material being cut.)

  D. Use sufficient pressure on the forward stroke

  E. Use full length of blade on each stroke

X. Principal parts of twist drill

  A. Shank

  B. Flute

  C. Cutting edge

XI. Ways to extract a screw

  A. Screw extractor

  B. Stud puller

  C. Diamond point chisel

XII. Types of pullers (Transparency 12)

  A. External

  B. Press

  C. Internal

XIII. Tools used for measuring speed

  A. Revolution counter

  B. Tachometer

  C. Timing light (Stroboscope)

XIV. Types of feeler gauges

  A. Standard

  B. Stepped

INFORMATION SHEET

XV. Types of taps and their functions (Transparency 13)

(NOTE: Taps are used for cutting internal threads.)

A. Taper--Used to start the thread

B. Plug--Used after taper tap has cut the threads as far as possible

C. Bottoming--Used last to cut the thread to the bottom of the hole (if necessary)

XVI. Right and wrong use of tools (Transparencies 14, 15, 16, and 17)

A. Hammer

B. Hacksaw blade

C. Pliers

D. Cold chisel

E. Grinding screwdriver

F. Grinding flat cold chisel

G. Screwdriver

H. End wrench

I. Adjustable wrench

J. End wrench-adjustable wrench

K. File

L. File card-wrench extension

M. File handle-hammer handle

XVII. Types of micrometers (Transparency 18)

A. Outside

B. Inside

C. Depth

D. Vernier

INFORMATION SHEET

XVIII. Reading the micrometer (Transparencies 19, 20, and Overlay 20A)

A. Each numbered graduation on the sleeve represents one hundred thousandths of an inch (0.100")

B. Each small graduation on the sleeve between the numbered graduations represents twenty-five thousandths of an inch (0.025")

C. Each graduation found on the thimble represents one thousandth of an inch (0.001")

D. Total reading is found by adding the three values

Example:	0.100	Number on the sleeve
	0.075	Small graduations on the sleeve
	0.015	Graduations on the thimble
	0.190	Micrometer reading

XIX. Reading the vernier micrometer (Transparencies 20, 21, and Overlays 20A and 21A)

A. Each numbered graduation on the sleeve represents one hundred thousandths of an inch (0.100")

B. Each small graduation on the sleeve between the numbered graduations represents twenty-five thousandths of an inch (0.025")

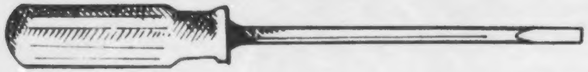
C. Each graduation found on the thimble represents one thousandth of an inch (0.001")

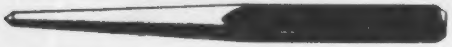
D. Each line graduation found on top of the sleeve represents one ten-thousandth of an inch (0.0001")

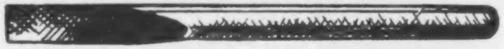
E. Total reading is found by adding the four values

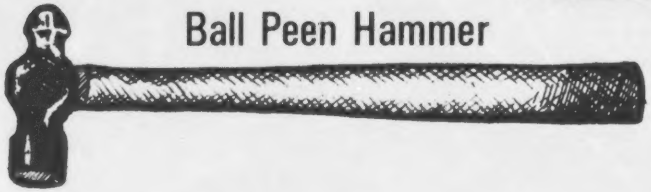
Example:	0.4000	Number on the sleeve
	0.0250	Small graduations on the sleeve
	0.0190	Graduations on the thimble
	0.0006	Vernier scale on top of sleeve
	0.4446	Vernier micrometer reading

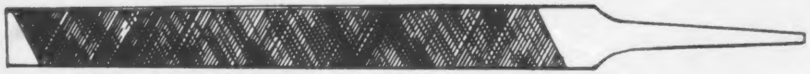
Basic Shop Tools

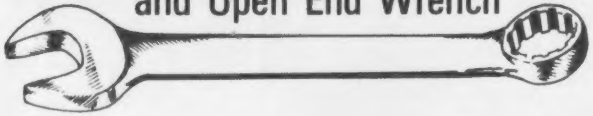

Common Screwdriver

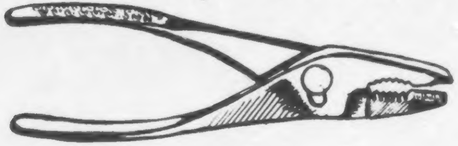

Center Punch

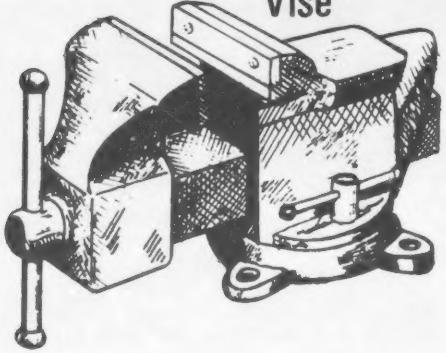

Flat Cold Chisel

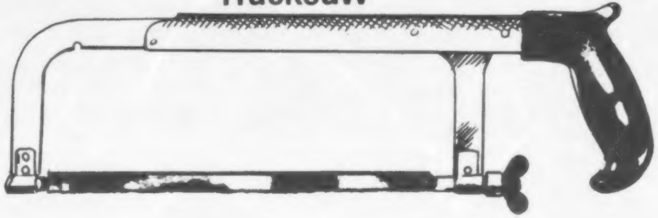

Ball Peen Hammer


Flat File


Combination Box
and Open End Wrench


Slip Joint Pliers


Vise

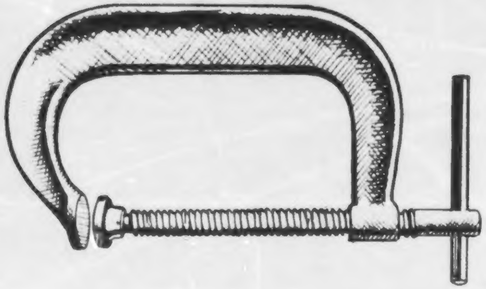

Hacksaw

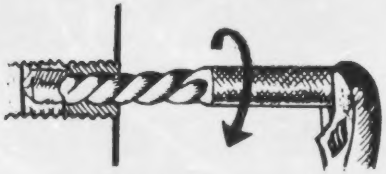
TM 1

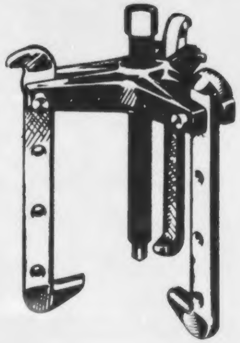
D:F - 53-A

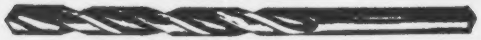
Basic Shop Tools

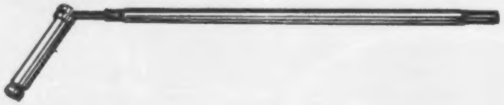
(Continued)

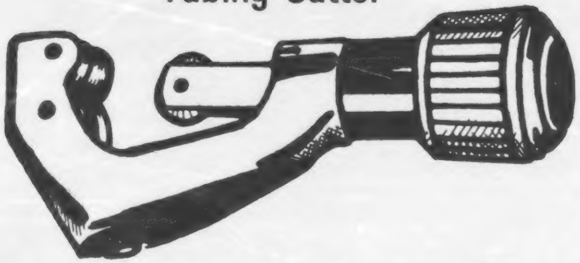

"C" Clamp

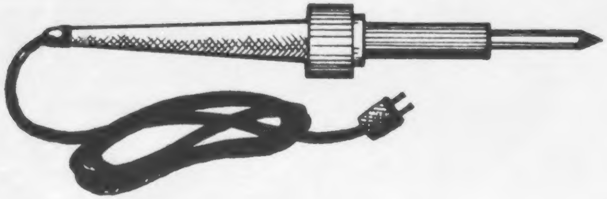

Screw Extractor


External Puller


Twist Drill


Magnetic Pick-Up Tool

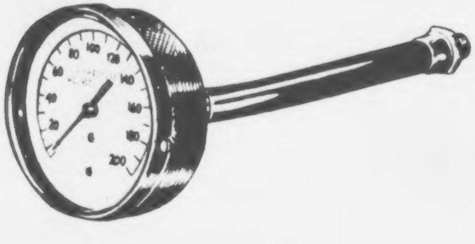

Tubing Cutter


Soldering Iron

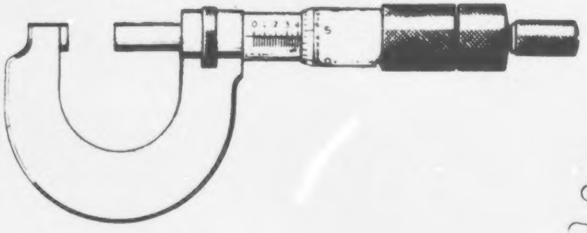
Basic Shop Tools

(Continued)

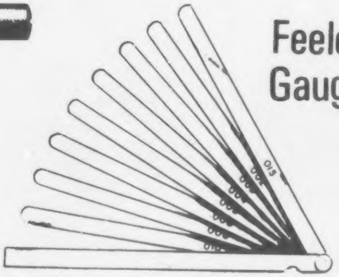
**Pressure Gauge
(oil pressure)**



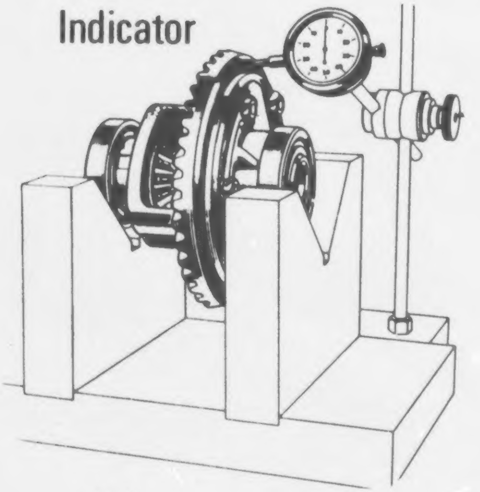
Outside Micrometer



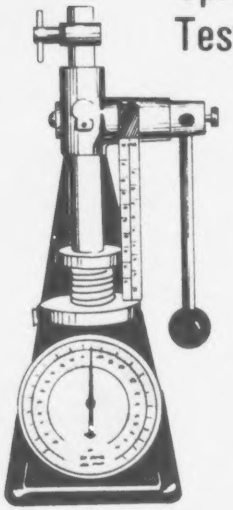
Feeler Gauge



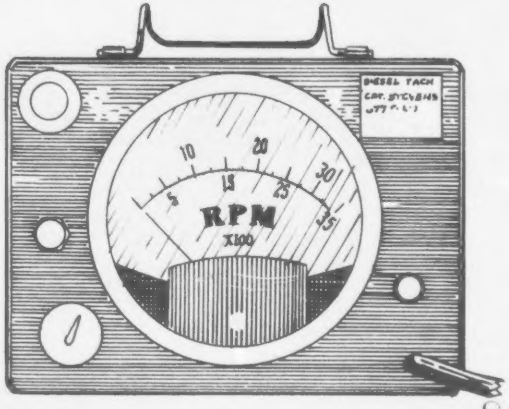
Dial Indicator



Spring Tester

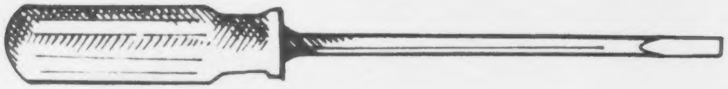


Tachometer

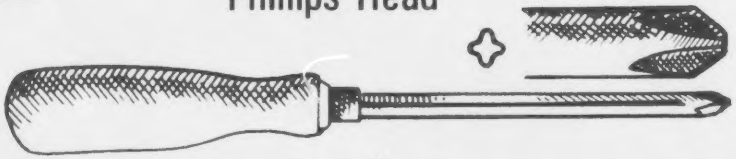

5
10
15
20
25
30
35
RPM
X100

Types of Screwdrivers

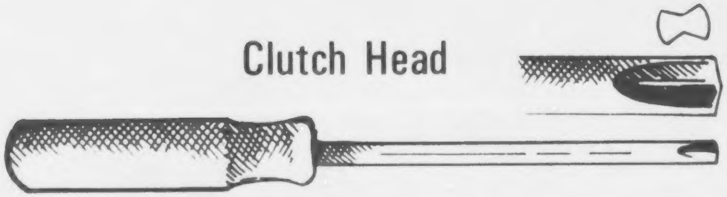
Common



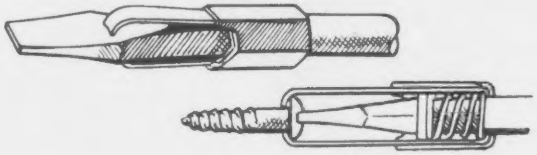
Phillips Head



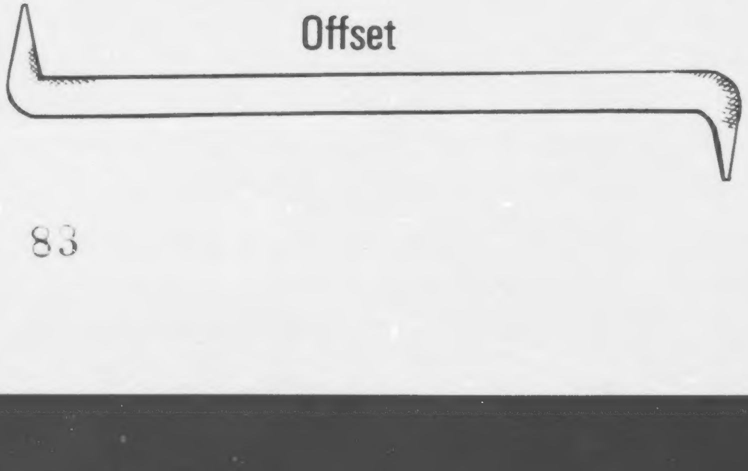
Clutch Head



Starting Screwdriver
(Shown Holding Screw)

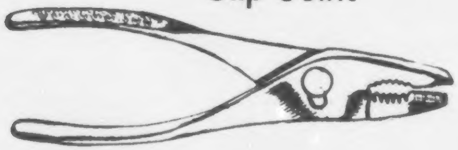


Offset

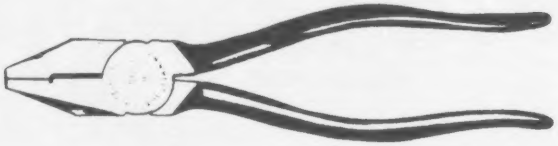


Types of Pliers

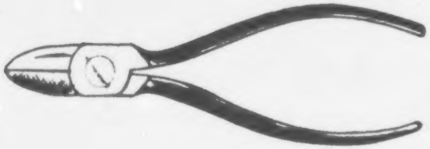
Slip Joint



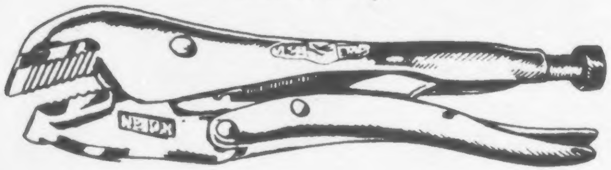
Side Cutters



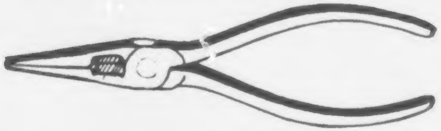
Diagonal Cutters



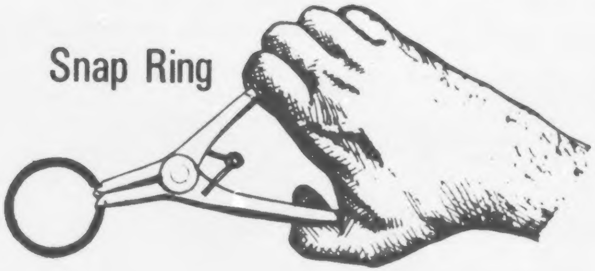
Lock Grip



Needle Nose

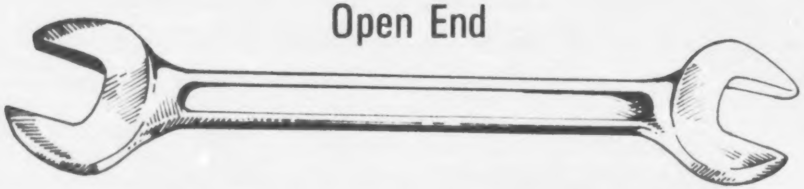


Snap Ring

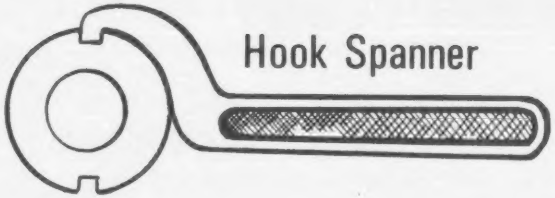


Types of Wrenches

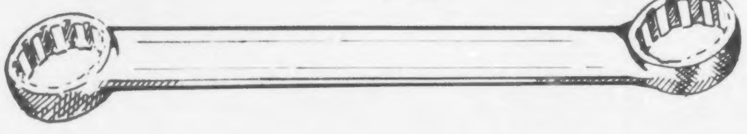
Open End



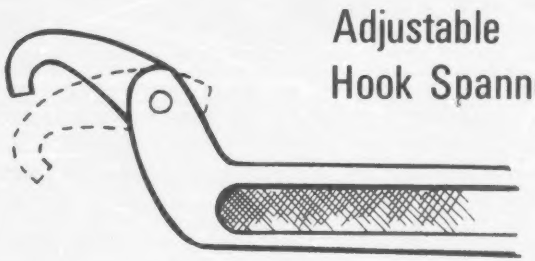
Hook Spanner



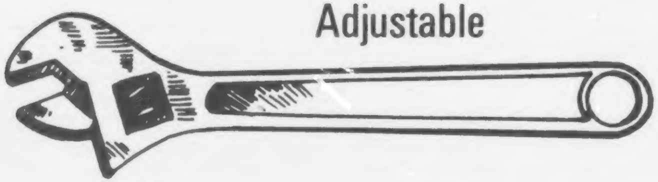
Box



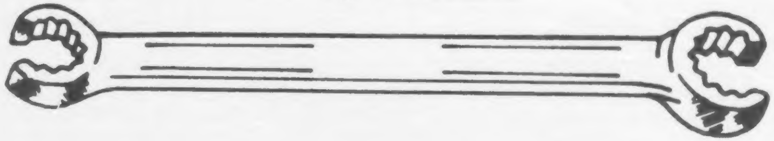
Adjustable
Hook Spanner



Adjustable



Tubing Wrench

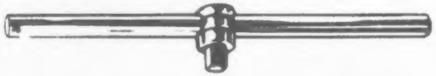


Types of Wrenches

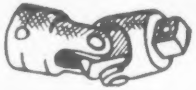
(Continued)

Socket Wrenches and Handles

Sliding "T" Handle

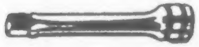


Universal Joint

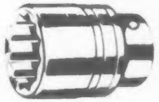


Ratchet Handle

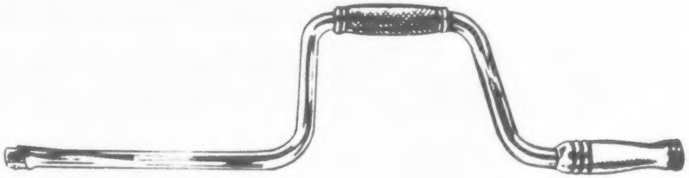
Extension



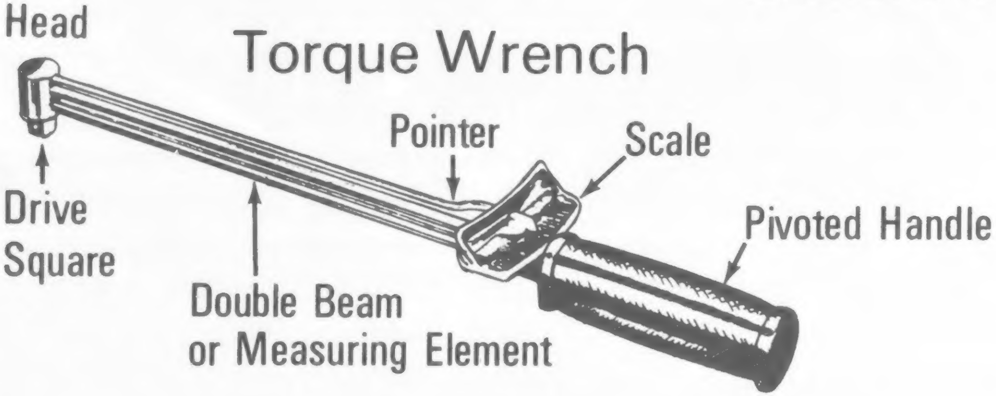
Socket

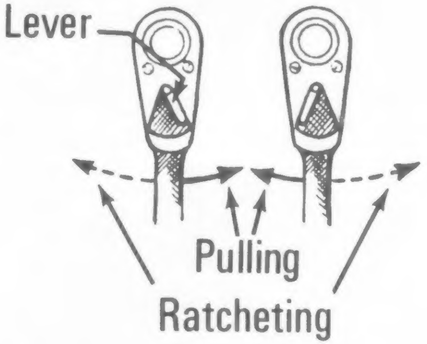


Speed Handle



Torque Wrench

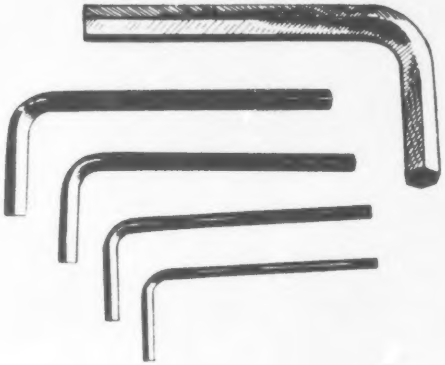

Head
Drive Square
Pointer
Scale
Pivoted Handle
Double Beam or Measuring Element


Lever
Pulling
Ratcheting

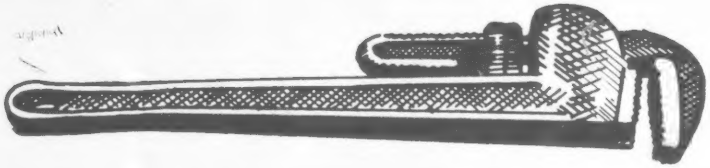
Types of Wrenches

(Continued)

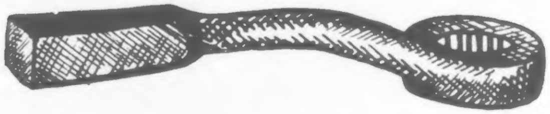
Allen



Pipe

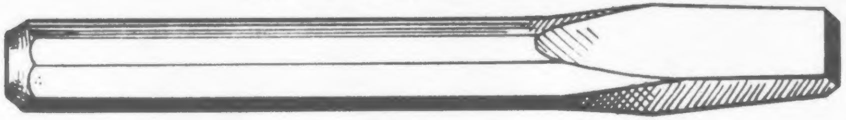


Striking

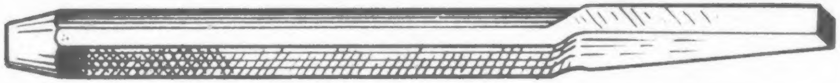


Types of Cold Chisels

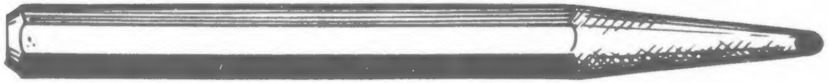
Flat Chisel



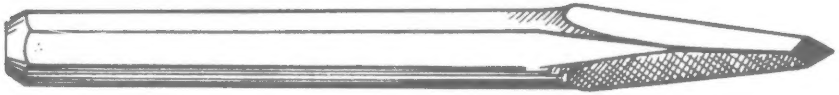
Cape Chisel



Round Nose Chisel

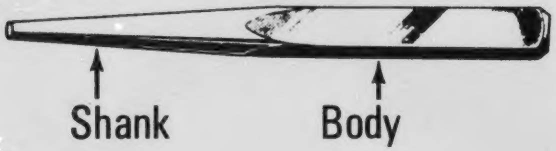


Diamond Point Chisel

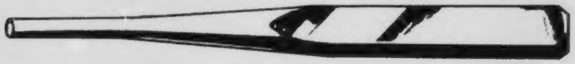


Types of Punches

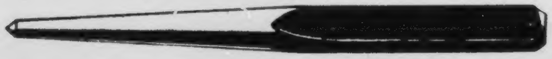
Starting Punch



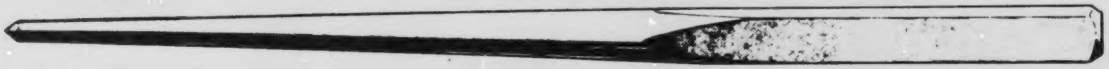
Pin Punch



Center Punch

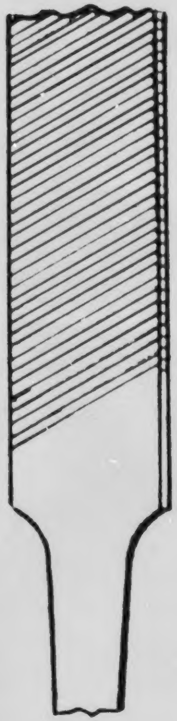


Aligning Punch

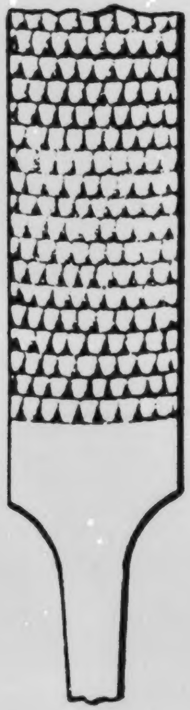


Types of File Teeth

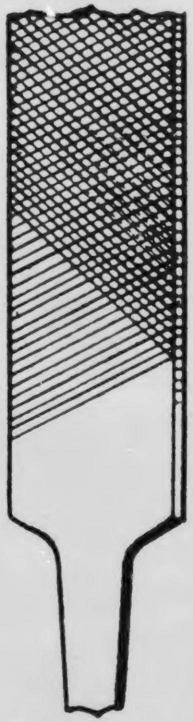
Single Cut



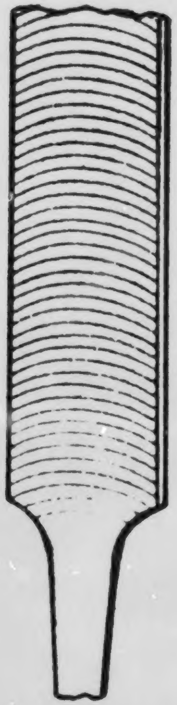
Rasp Cut



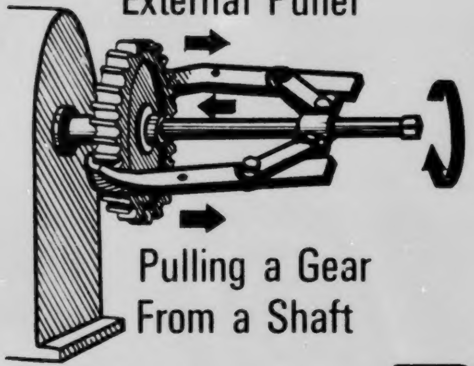
Double Cut



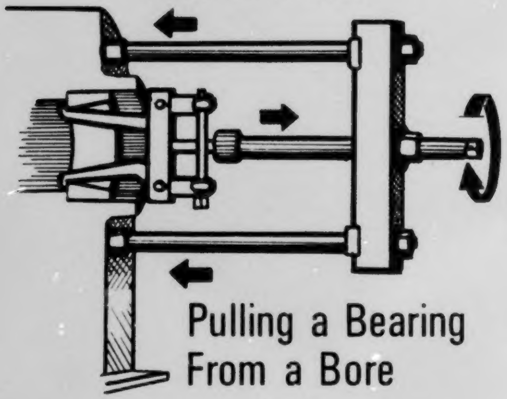
Curved Tooth



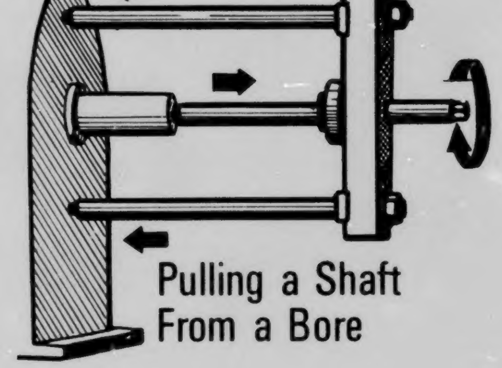
Types of Pullers


External Puller

Pulling a Gear From a Shaft

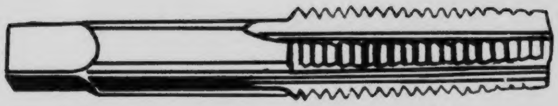

Internal Puller

Pulling a Bearing From a Bore

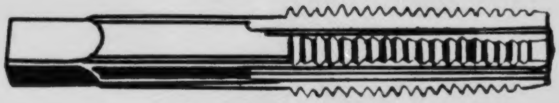

Press-Puller

Pulling a Shaft From a Bore

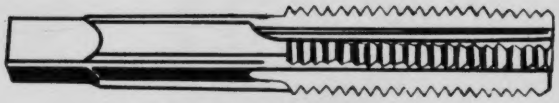
Types of Taps



Taper



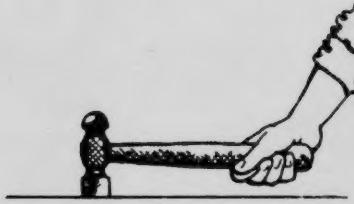
Plug



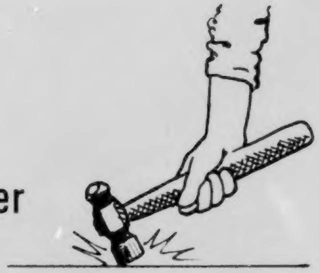
Bottoming

Right and Wrong Use of Tools

Hammer

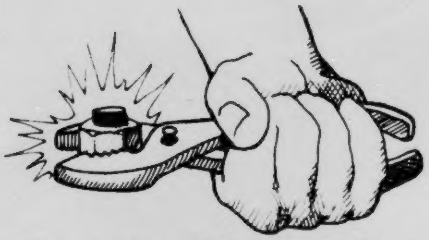


Right



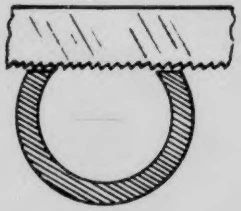
Wrong

Pliers

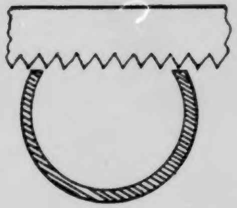


Don't Use Pliers on Nuts

Hacksaw Blade

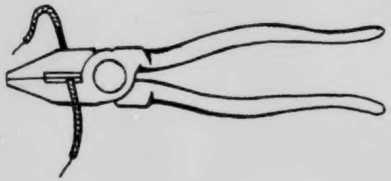


Right Blade



Wrong Blade

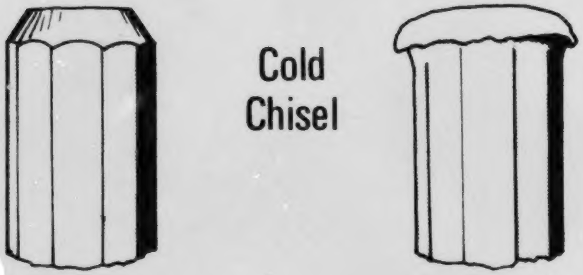
Side Cutters



Use Side Cutters to Cut Wire

Right and Wrong Use of Tools

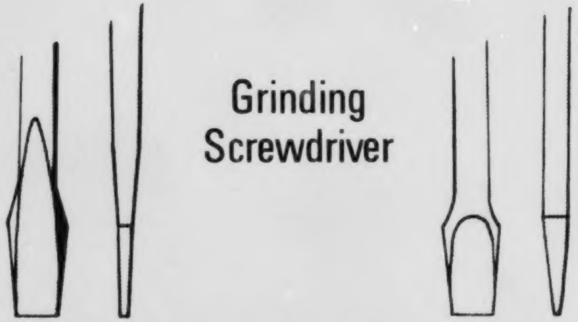
(Continued)



Cold Chisel

Right

Wrong

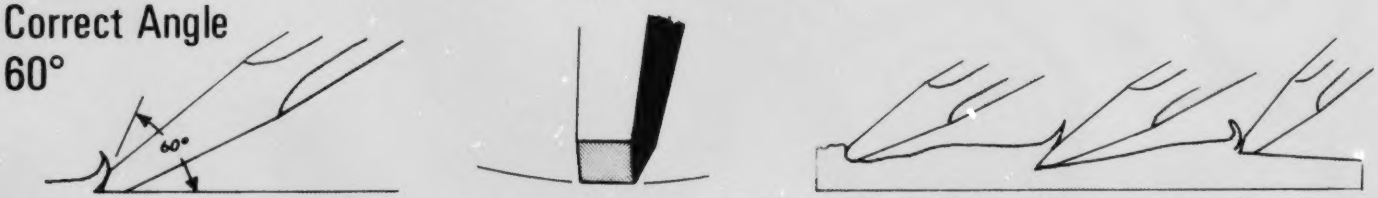


Grinding Screwdriver

Right

Wrong

Grinding Flat Cold Chisel



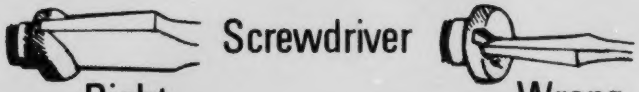
Correct Angle 60°

Round Edge Slightly

Rounded and Dull

Angle is too Small

Angle is too Large



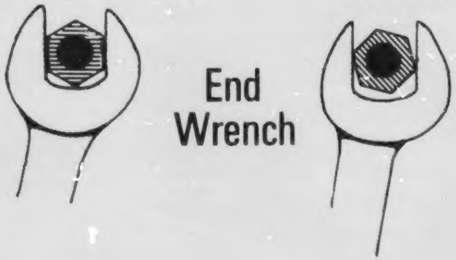
Screwdriver

Right

Wrong

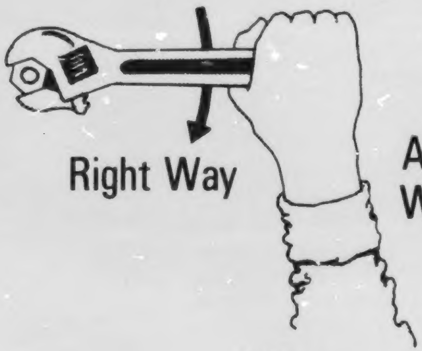
Right and Wrong Use of Tools

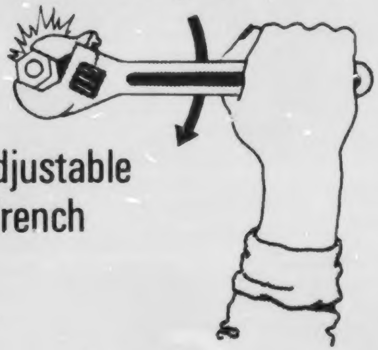
(Continued)


Right

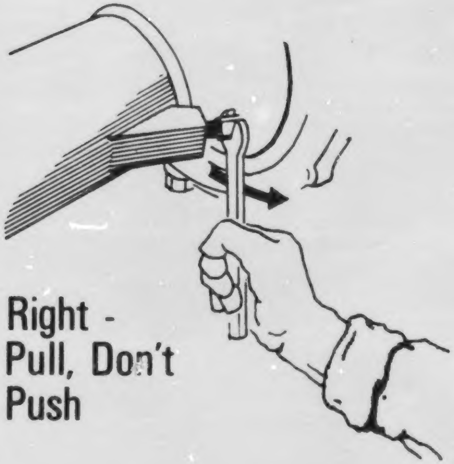
Wrong

End Wrench

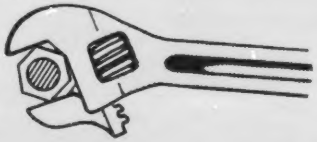

Right Way


Wrong Way

Adjustable Wrench

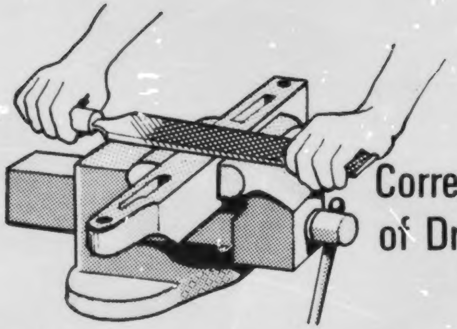

Right - Pull, Don't Push

End Wrench - Adjustable Wrench


Wrong - Don't Pull on an Adjustable Wrench Until It has Been Tightened on the Nut

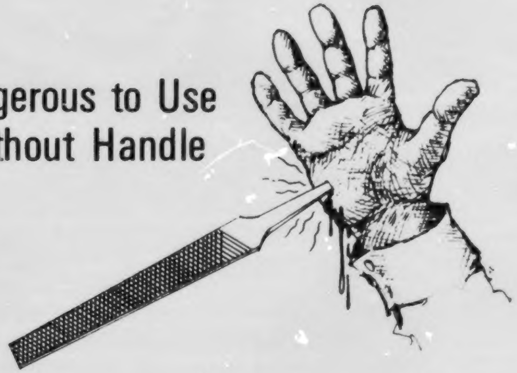
Right and Wrong Use of Tools

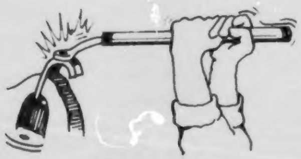
(Continued)



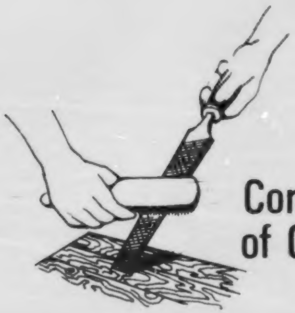
Correct Method of Draw-Filing

It is Dangerous to Use a File Without Handle

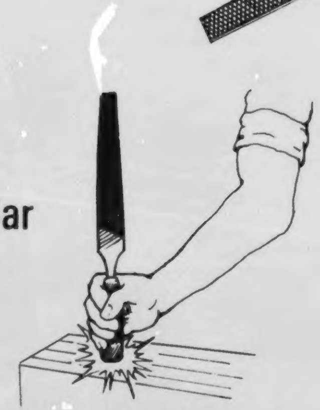




Wrong - Never Use a Bar or a Pipe on a Wrench

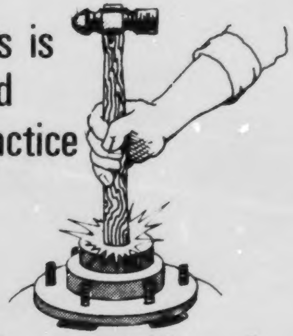


Correct Method of Cleaning a File



Correct Method of Tightening File Handle

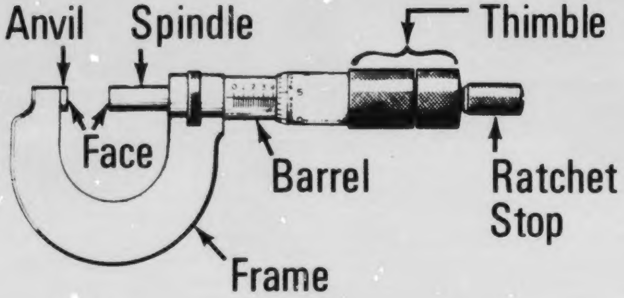
This is Bad Practice



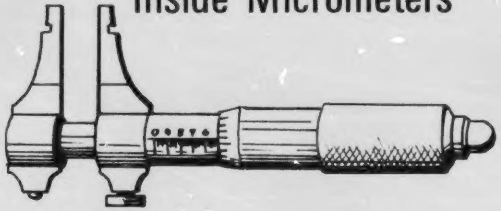
Incorrect Use of a Hammer

Types of Micrometers

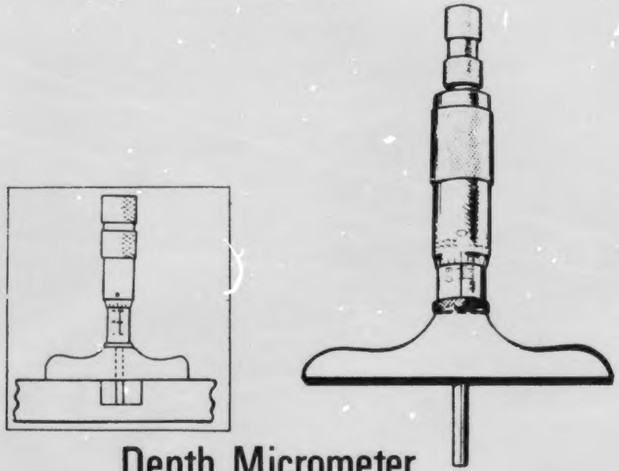
Outside Micrometer


Anvil
Spindle
Thimble
Face
Barrel
Ratchet Stop
Frame

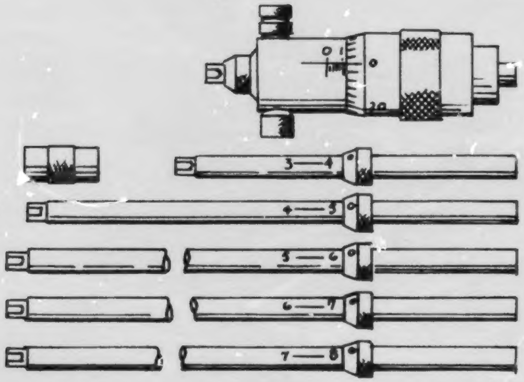
Inside Micrometers



Small Inside Diameter Micrometer

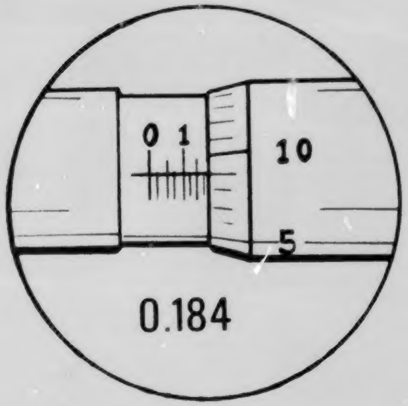


Depth Micrometer

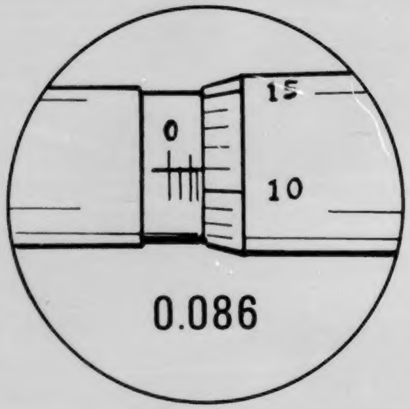


Large Inside Diameter Micrometer

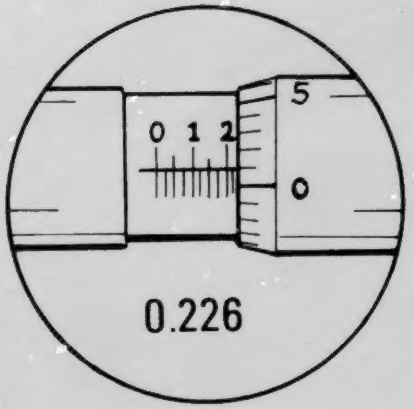
Reading a Micrometer



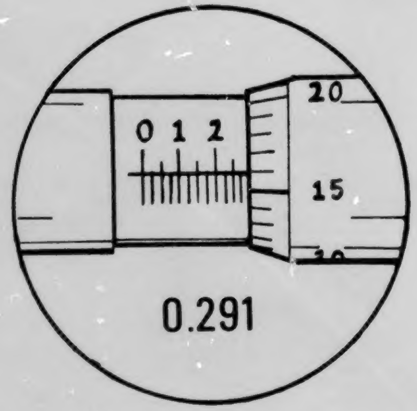
0.184



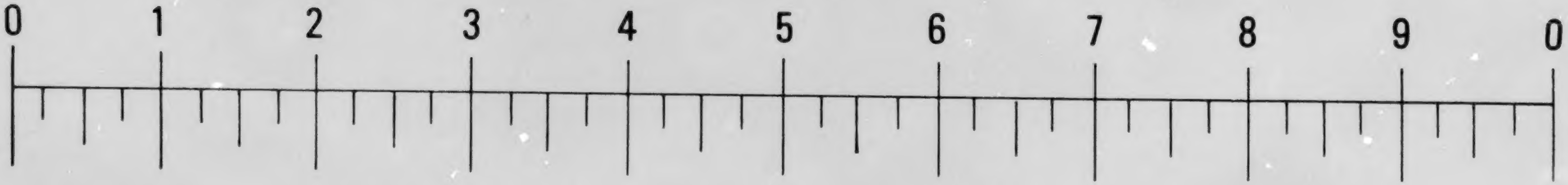
0.086



0.226

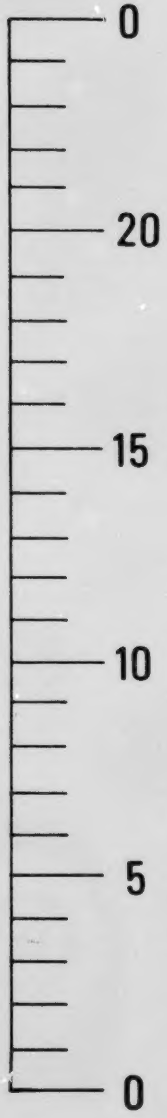


0.291

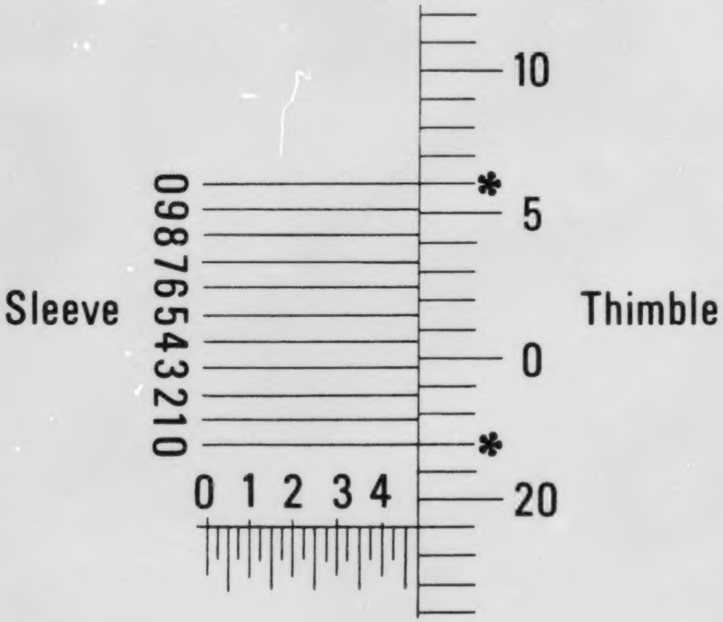

0
1
2
3
4
5
6
7
8
9
0

Sleeve Readings

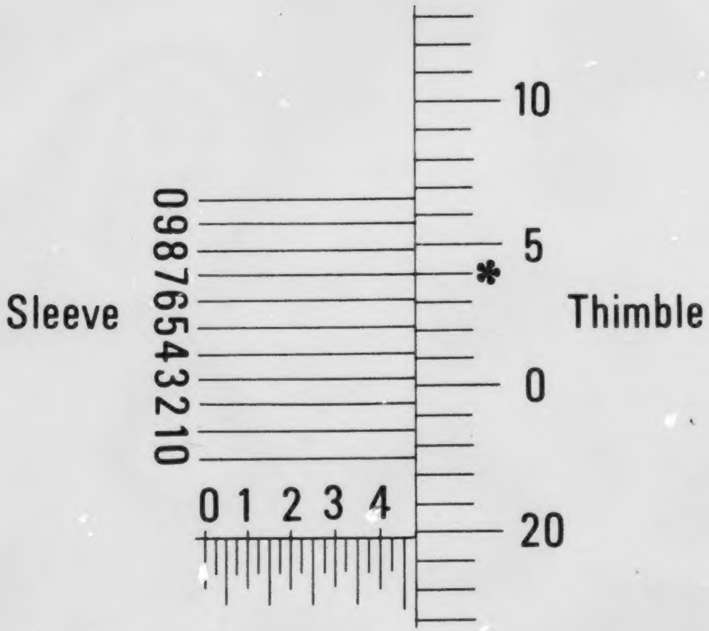
Thimble Sleeve Readings



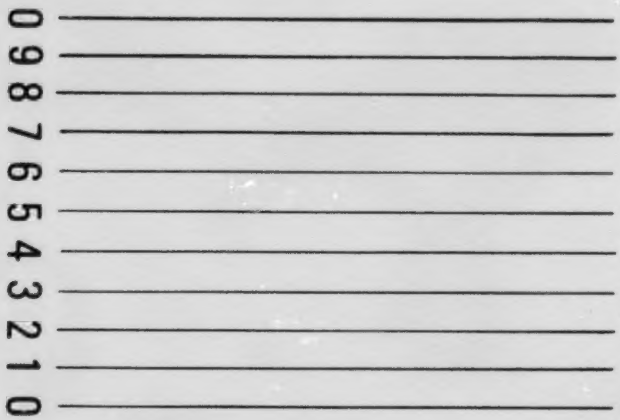
Vernier Micrometer Readings


Sleeve
0987654321 0
0 1 2 3 4
Thimble
10
5
0
20
*
*

0.4690


Sleeve
0987654321 0
0 1 2 3 4
Thimble
10
5
0
20
*

0.4697

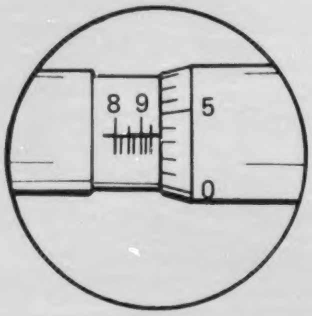

0
9
8
7
6
5
4
3
2
1
0

Vernier Sleeve Readings

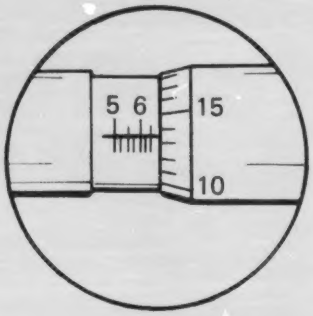
BASIC SHOP TOOLS
UNIT III

ASSIGNMENT SHEET #1--READ THE MICROMETER SETTINGS

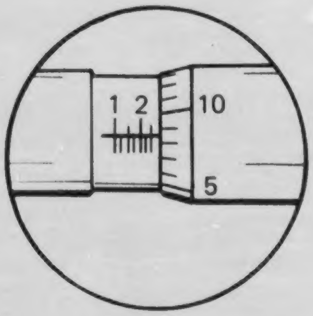
Directions: Read the micrometer settings below and write the correct answers in the blanks provided.



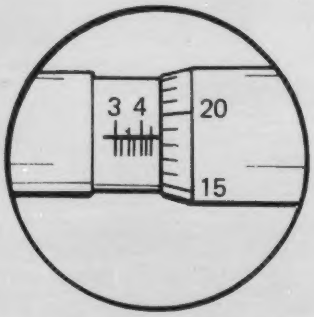
a. ______________________________



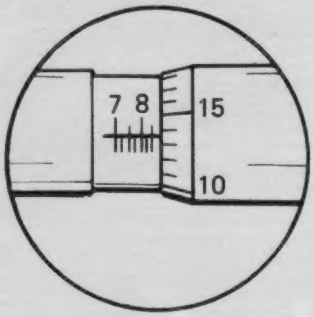
b. ______________________________



c. ______________________________

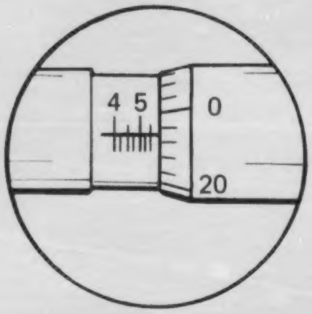


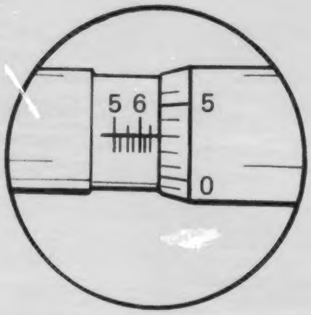
d. ______________________________



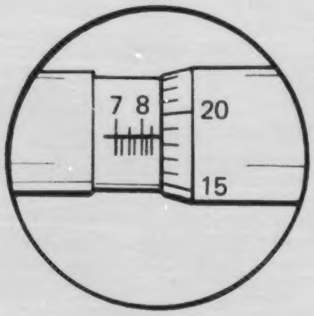
e. ______________________________

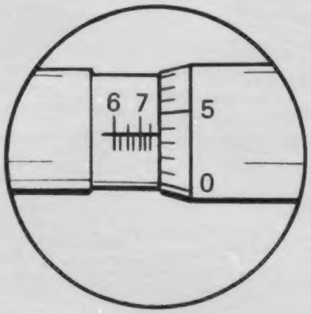
ASSIGNMENT SHEET #1



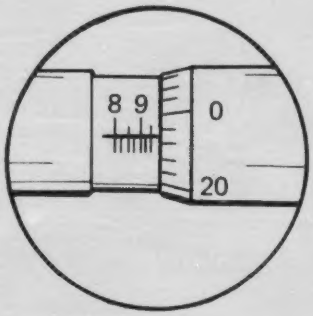


f. ______________________ g. ______________________





h. ______________________ i. ______________________



j. ______________________

BASIC SHOP TOOLS
UNIT III

ASSIGNMENT SHEET #2--READ THE VERNIER MICROMETER SETTINGS

Directions: Read the vernier micrometer settings below and write the correct answers in the blanks provided.

Answers

a. ____________________

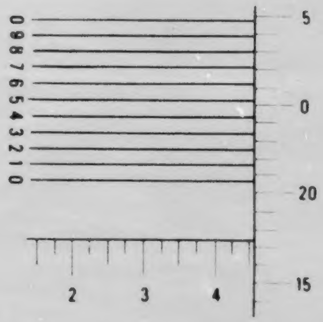
b. ____________________

c. ____________________

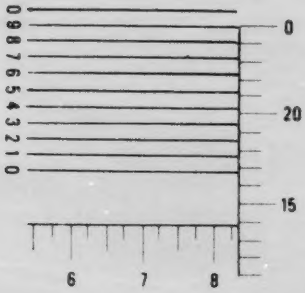
d. ____________________

e. ____________________

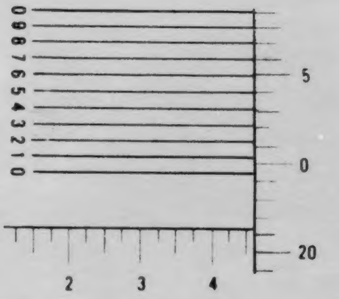
a.


0 9 8 7 6 5 4 3 2 1 0
5
0
20
15
2
3
4

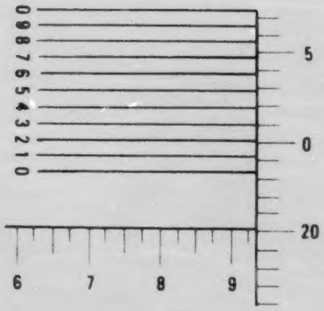
b.


0 9 8 7 6 5 4 3 2 1 0
0
20
15
6
7
8

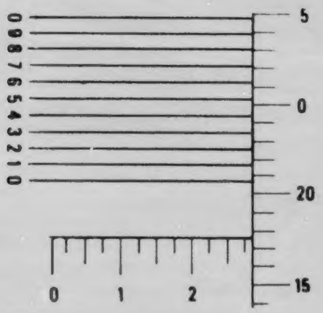
c.


0 9 8 7 6 5 4 3 2 1 0
5
0
20
2
3
4

d.


0 9 8 7 6 5 4 3 2 1 0
5
0
20
6
7
8
9

e.


0 9 8 7 6 5 4 3 2 1 0
5
0
20
15
0
1
2

BASIC SHOP TOOLS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. 0.953

b. 0.664

c. 0.258

d. 0.468

e. 0.863

f. 0.598

g. 0.653

h. 0.868

i. 0.753

j. 0.973

Assignment Sheet #2

a. 0.4678

b. 0.8388

c. 0.4715

d. 0.9453

e. 0.2928

BASIC SHOP TOOLS
UNIT III

JOB SHEET #1--SHARPEN A TWIST DRILL

I. Tools and materials

  A. Grinder

  B. Twist drill

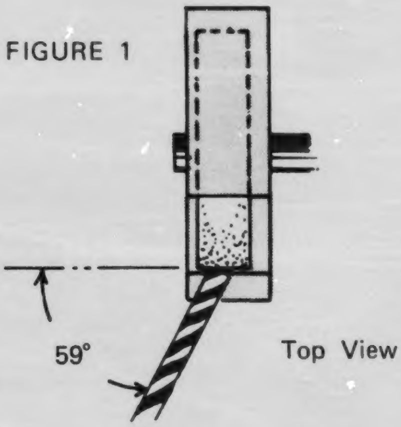
  C. Container of water

II. Procedure

(CAUTION: Follow all shop safety procedures.)

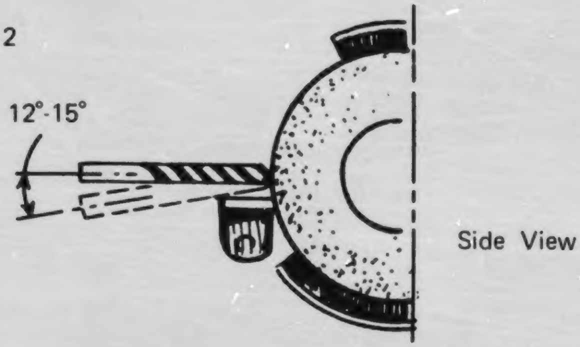
  A. Place the drill point against the grinding wheel at approximately a 59° angle (Figure 1)

FIGURE 1



  B. Using both hands, lower the shank, and raise the bit cutting point against the wheel (Figure 2)

FIGURE 2



JOB SHEET #1

C. Rotate the bit in a clockwise manner while grinding

D. Grind both lips in the same manner

E. Dip the point in water frequently to keep it cool

BASIC SHOP TOOLS
UNIT III

JOB SHEET #2--DRILL HOLES WITH A DRILL PRESS

I. Tools and materials

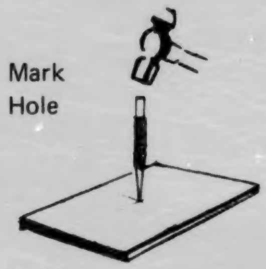
- A. Small piece of flat metal
- B. Drill press
- C. Center punch
- D. Hammer
- E. Wooden block
- F. Cutting oil
- G. Clamp
- H. Safety goggles

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Mark the hole with a center punch (Figure 1)

FIGURE 1

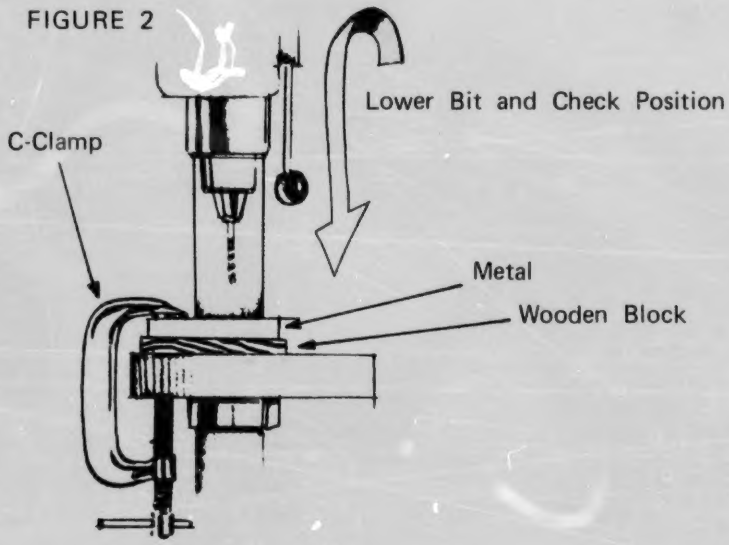


B. Place the metal on a wooden block

JOB SHEET #2

C. Clamp the metal being drilled securely to prevent it from spinning (Figure 2)

FIGURE 2


Lower Bit and Check Position
C-Clamp
Metal
Wooden Block

D. Feed the bit down to the metal and start drilling

(CAUTION: Select proper drill speed, if available.)

E. Raise the bit to see if you are drilling in the proper place

F. Continue drilling, using cutting oil on the drill bit two or three inches above the work

BASIC SHOP TOOLS
UNIT III

JOB SHEET #3--RESHAPE A COLD CHISEL

I. Tools and materials

   A. Cold chisel

   B. Grinder

   C. Container of water

   D. Eye protection

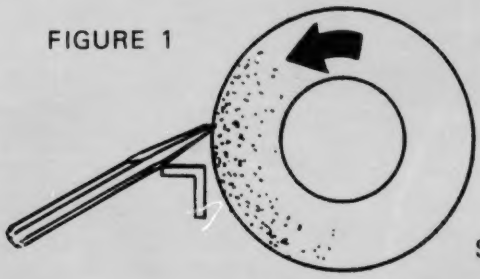
II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Hold the chisel at a 65° to 70° angle with the handle pointing down (Figure 1)

      (CAUTION: Check tool rest for proper adjustment.)

FIGURE 1

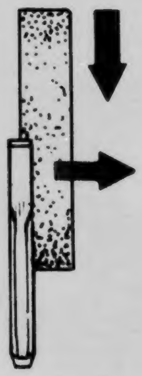


Side View

JOB SHEET #3

B. Move the point from side to side across the grinding wheel (Figure 2)

FIGURE 2

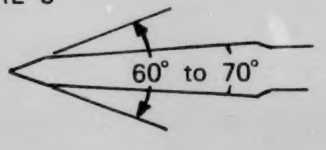


Top View

(NOTE: Dip the point in water frequently to keep it cool.)

C. Grind both sides of the cutting edge in the same manner (Figure 3)

FIGURE 3



D. Dip the point in water frequently to keep it cool

E. If the head has become mushroomed, it should be ground back into shape

BASIC SHOP TOOLS
UNIT III

JOB SHEET #4--CUT FLAT METAL WITH A COLD CHISEL

I. Tools and materials

   A. Marker (oval or chalk)

   B. Flat strip of metal

   C. Chisel

   D. Hammer

   E. Vise

   F. Eye protection

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Mark the metal

   B. Place the metal in the vise with the cutting mark just above the jaws of the vise

   C. Select proper size chisel and hammer

      (NOTE: For larger size metal, use a larger chisel and hammer.)

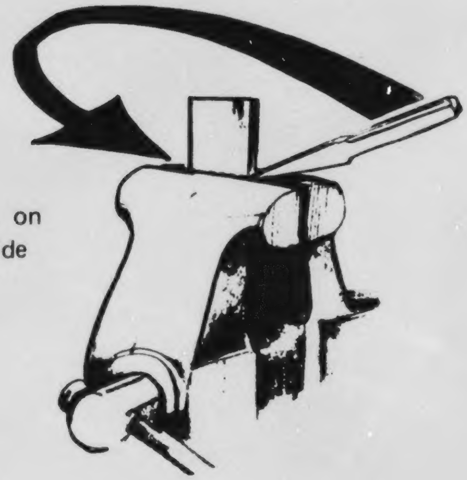
   D. Place the chisel at side of the metal to start the shearing point

      (NOTE: Drive the chisel with a hammer.)

JOB SHEET #4

E. Hold the chisel at approximately a 30° angle from line of cut (Figure 1)

FIGURE 1



Repeat Cut on Opposite Side

F. Make cuts from each end of the metal to the center and on both sides

G. Bend metal back and forth until it breaks

BASIC SHOP TOOLS
UNIT III

JOB SHEET #5--DRESS A GRINDING WHEEL

I. Tools and materials

  A. Grinding wheel

  B. Dressing tool

  C. Eye protection

II. Procedure

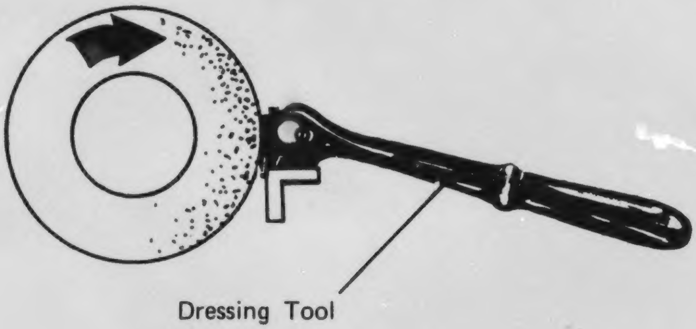
(CAUTION: Follow all shop safety procedures.)

  A. Select the proper dressing tool

  B. Set the dressing tool on the grinder tool rest and press it firmly against the wheel (Figure 1)

  (NOTE: Use enough pressure on the tool to prevent sparks.)

FIGURE 1



  C. Dress the grinder wheel with the tool until the edges are square with the sides

BASIC SHOP TOOLS
UNIT III

JOB SHEET #6- REGRIND A SCREWDRIVER

I. Tools and materials

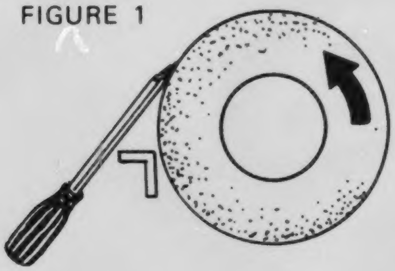
- A. Grinder
- B. Screwdriver
- C. Screw with head size equal to the width of the screwdriver's blade
- D. Container of water
- E. Eye protection

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Place screwdriver against the grinder wheel at a 90° angle to square the tip
- B. Apply light pressure on blade, while grinding
- C. Shape both faces of screwdriver (Figure 1)

FIGURE 1



- D. Use screw head to determine the extent of grinding desired

JOB SHEET #6

(NOTE: Do not round or sharpen the end. See Figure 2.)

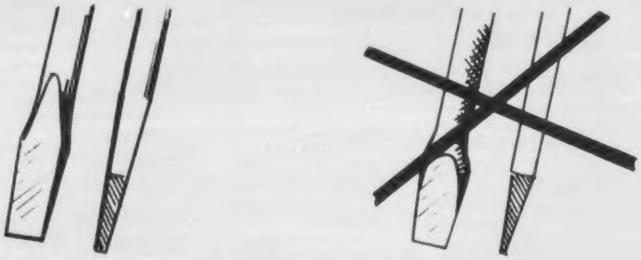


FIGURE 2 Ground Right Ground Wrong

E. Dip point in water frequently to keep it cool

BASIC SHOP TOOLS
UNIT III

JOB SHEET #7--REPLACE A HAMMER HANDLE

I. Tools and materials

A. Hammer with a broken handle

B. Hacksaw

C. Twist drill

D. Punch

E. Rasp

F. Handsaw

G. Soft faced hammer

H. Vise

(NOTE: Cover the jaws of the vise with sheet metal or use wood blocks to prevent damage to the hammer and handle.)

I. New handle

J. Small piece of wood for wedge

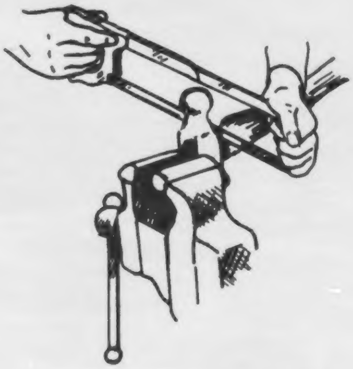
II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Place the hammer head in the vise

B. Saw the broken handle close to the hammer head with a hacksaw (Figure 1)

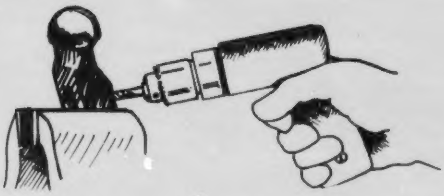
FIGURE 1



JOB SHEET #7

C. Remove the wood from the eye by first drilling with a twist drill and then punching the remainder out (Figure 2)

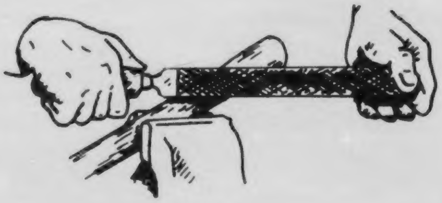
FIGURE 2



D. Place the new handle in the vise

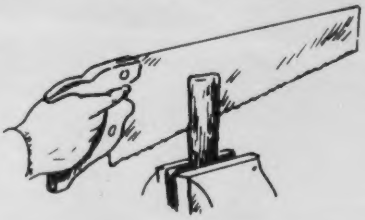
E. Work the new handle down to size with a rasp, trying the handle in the head frequently (Figure 3)

FIGURE 3



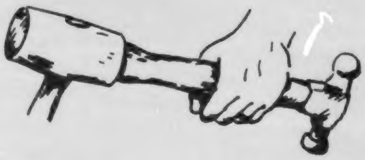
F. With a handsaw make a cut across the long diameter of the top of the handle to a distance of about 2/3 the depth of the eye (Figure 4)

FIGURE 4



G. Drive the handle firmly into place using a soft faced hammer (Figure 5)

FIGURE 5



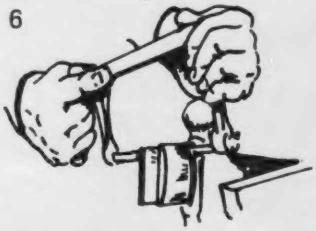
H. Use a thin metal wedge and drive it tightly into the cut in the end of the handle

JOB SHEET #7

I. Place the hammer in the vise and use a hacksaw to cut off the handle and wedge extending through the head (Figure 6)

(NOTE: If steel wedges are used, the end of the handle need not be cut across the diameter, as the wedge can be driven into place after the handle has been cut off even with the head.)

FIGURE 6



BASIC SHOP TOOLS
UNIT III

JOB SHEET #8--TIN A SOLDERING IRON

I. Tools and materials

   A. Soldering iron

   B. File

   C. Zinc chloride, sal ammoniac, or powdered rosin

   D. Solder

   E. Gas furnace or torch (if a nonelectric iron is being used)

   F. Clean cloth

   G. Eye protection

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Clean the four faces of the point with a file

      (NOTE: This is necessary for removing rough spots from copper.)

   B. Heat the iron until it will melt solder

   C. Continue with one of the following three ways depending on materials available

      (CAUTION: Provide adequate ventilation.)

      1. Zinc chloride

         a. Dip point quickly into and out of a jar of zinc chloride

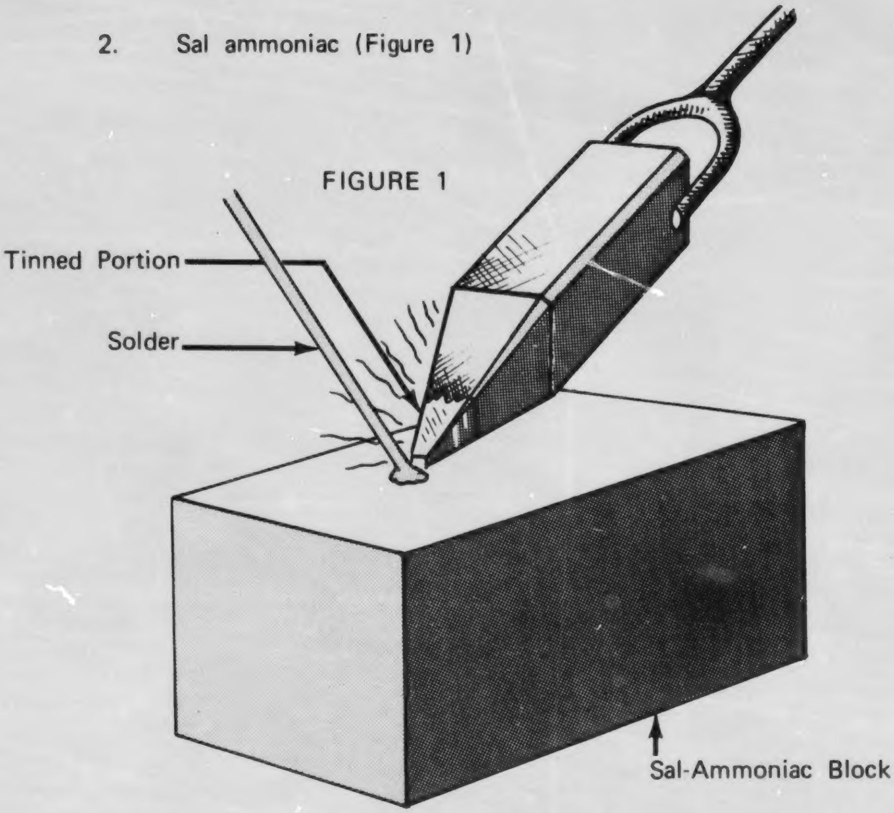
         b. Melt solder on the faces

         c. Wipe with a clean cloth to remove excess solder

JOB SHEET #8

2. Sal ammoniac (Figure 1)

FIGURE 1


Tinned Portion
Solder
Sal-Ammoniac Block

   a. Drop a few drops of solder on the sal ammoniac block

   b. Rub the tip in the drops on the block

   c. Remove excess solder by wiping the tip with a clean cloth

3. Rosin

   a. Rub the tip in powdered rosin

   b. Dip the tip in solder

   c. Wipe with a clean cloth to remove excess solder

BASIC SHOP TOOLS
UNIT III

JOB SHEET #9--CHECK A TORQUE WRENCH FOR ACCURACY

I. Tools and materials

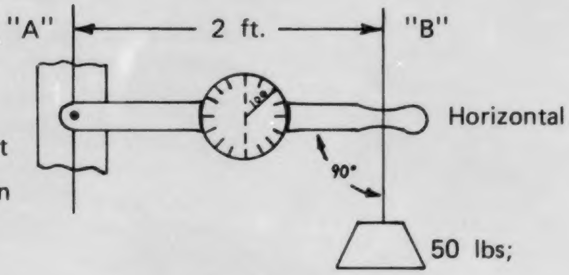
- A. Torque wrench
- B. Vise
- C. "Known" weight
- D. Strong cord

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Hang torque wrench on a fixed nut or secure in a vise (Figure 1)

FIGURE 1



A=Center Line of Nut

B=Point of Suspension

B. Set the indicator to "O"

C. Hang a known weight from the wrench handle at any known distance from the center of the nut (Figure 1)

D. Multiply the weight times the distance from A to B (Figure 1)

E. Compare the answer to the indicator reading

Example: In figure 1, 50 pounds x 2 feet = 100 foot pounds

BASIC SHOP TOOLS
UNIT III

JOB SHEET #10 - DRAW FILE A FLAT SURFACE

I. Tools and materials

   A. File handle

   B. Machinist's file

      (NOTE: Machinist's file has double cut teeth for cutting in both directions.)

   C. Vise

   D. Stock to be draw filed

II. Procedure

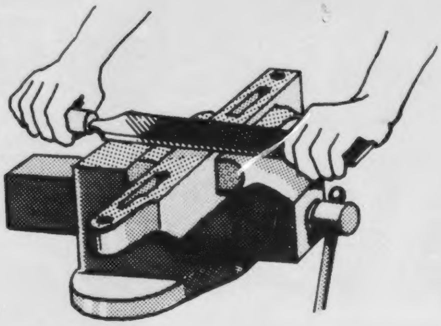
   (CAUTION: Follow all shop safety procedures.)

   A. Secure stock to be filed in vise

   B. Equip file with a tight fitting handle

   C. Draw the file crosswise over the work with a light pressure (Figure 1)

FIGURE 1



   D. Apply enough pressure to keep file cutting in both directions

BASIC SHOP TOOLS
UNIT III

JOB SHEET #11--DRAW A TWIST DRILL TO CORRECT CENTER

I. Tools and materials

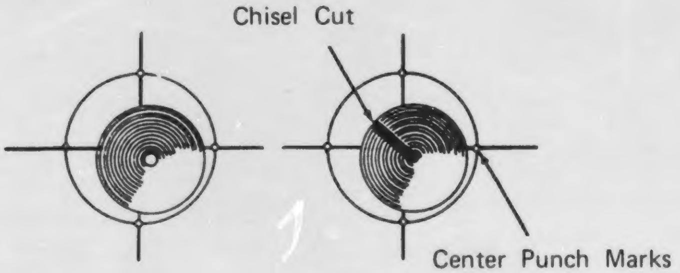
- A. Electric drill, 1/2" chuck
- B. High speed twist drill
- C. Center punch
- D. Ball peen hammer
- E. Stock to be drilled
- F. Lubricating oil

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Make a center punch mark on stock
- B. Enlarge the center punch mark slightly and remove before whole point has entered the material
- C. Make a chisel cut to side to which the drill should be drawn (Figure 1)

FIGURE 1



How to Draw the Drill Back to Correct Center

- D. Make another punch mark for new center
- E. Repeat step B above

BASIC SHOP TOOLS
UNIT III

JOB SHEET #12--USE THE OUTSIDE MICROMETER

I. Tools and materials

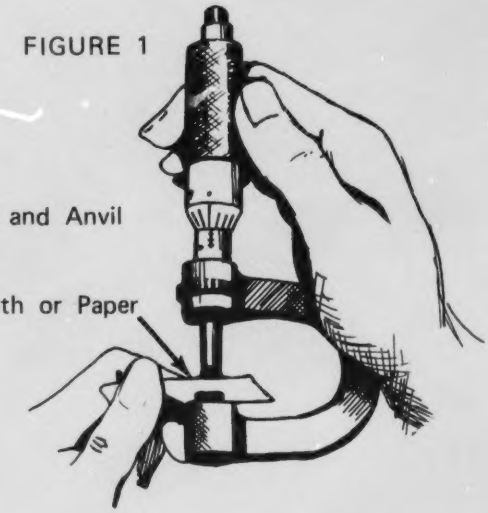
- A. 0" - 1.000" outside micrometer
- B. 1.000" - 2.000" outside micrometer
- C. Lathe or vise
- D. New fractional drill bits, assortment of 5
- E. New letter size drill bits, assortment of 5
- F. Pieces of metal such as cold rolled stock, machined parts, hardened dowels, assortment of 5

(NOTE: All workpieces should be numbered or lettered for reference.)

II. Procedure

- A. Select workpieces that are clean and free of burrs, nicks, or dents
- B. Select the proper size micrometer for the workpiece
- C. Clean the spindle and anvil of the micrometer (Figure 1)

FIGURE 1



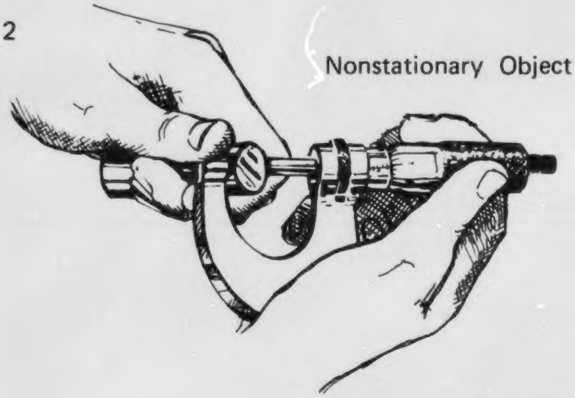
JOB SHEET #12

D. Check the micrometer at zero reference

E. Hold the micrometer according to the type of workpiece

1. Hold the micrometer in the right hand and the workpiece in the left hand to measure a nonstationary object (Figure 2)

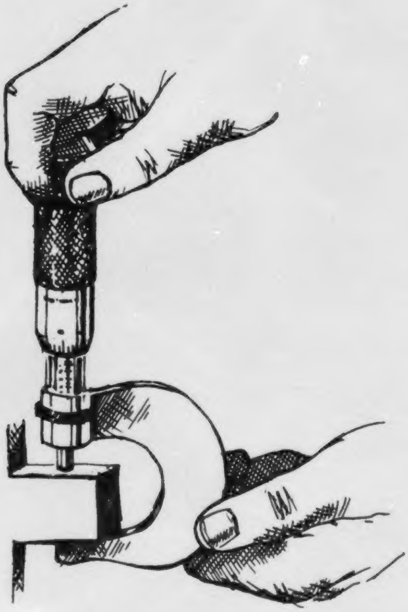
FIGURE 2



Nonstationary Object

2. Hold the micrometer in both hands to measure a stationary object (Figure 3)

FIGURE 3

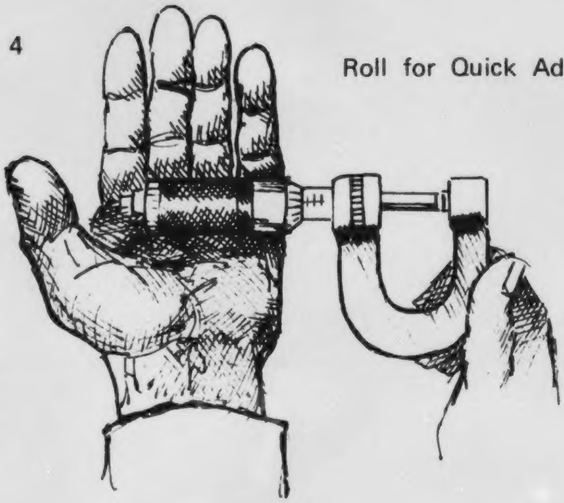


Stationary Object

JOB SHEET #12

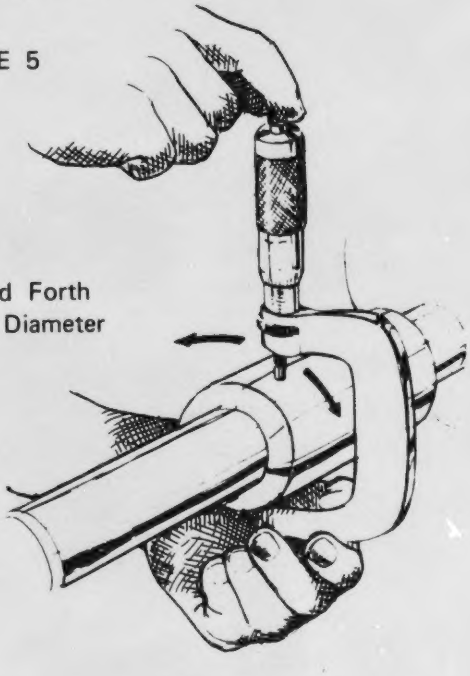
(NOTE: Roll micrometer along palm of hand or forearm for quick adjustment. See Figure 4.)

FIGURE 4


Roll for Quick Adjustment

F. Place the micrometer directly over the center of the workpiece to be measured (Figure 5)

FIGURE 5


Work Back and Forth
to Find True Diameter

JOB SHEET #12

G. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece

H. Hold the anvil steady and move the spindle lightly over the workpiece to locate the true centerline (Figure 5)

I. Use ratchet stop or light sense of feel to determine exact measurement

J. Observe micrometer readings

(NOTE: Spindle lock can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.)

K. List the readings according to the letter or number on the workpiece

L. Return the micrometer to its correct storage

(NOTE: The spindle and anvil of the micrometer should be left open when stored.)

M. Hand in the listed readings to the instructor for evaluation

BASIC SHOP TOOLS
UNIT III

JOB SHEET #13--USE THE VERNIER MICROMETER

I. Tools and materials

A. 0" - 1.0000" vernier micrometer

B. 1.0000" - 2.0000" vernier micrometer

C. Lathe or vise

D. New number drill bits, assortment of 5

E. New fractional drill bits, assortment of 5

F. Pieces of metal such as cold rolled stock, machined parts, hardened dowels, assortment of 5

(NOTE: All workpieces should be numbered or lettered for reference.)

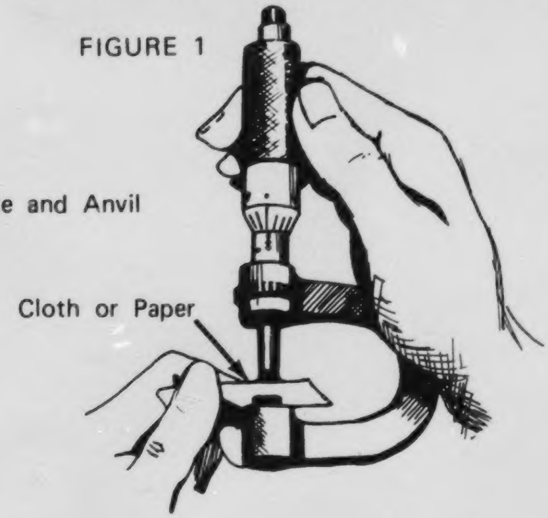
II. Procedure

A. Select workpieces that are clean and free of burrs, nicks, or dents

B. Select the proper size micrometer for the workpiece

C. Clean the spindle and anvil of the micrometer (Figure 1)

FIGURE 1



Clean Spindle and Anvil

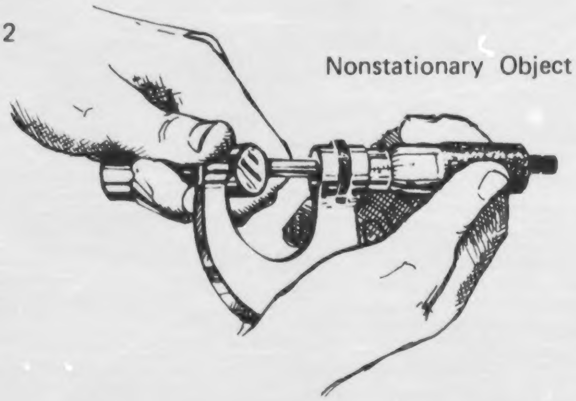
JOB SHEET #13

D. Check the micrometer at zero reference

E. Hold the micrometer according to the type of workpiece

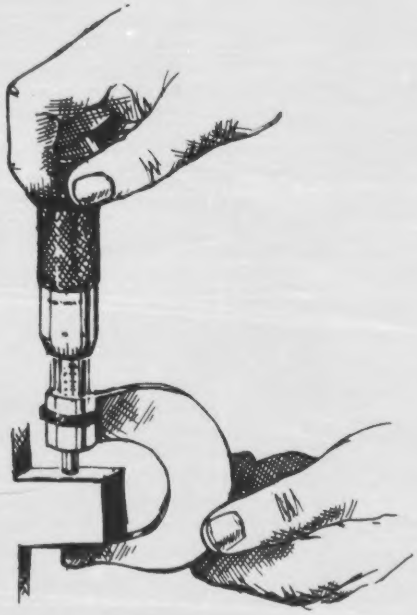
1. Hold the micrometer in the right hand and the workpiece in the left hand to measure a nonstationary object (Figure 2)

FIGURE 2


Nonstationary Object

2. Hold the micrometer in both hands to measure a stationary object (Figure 3)

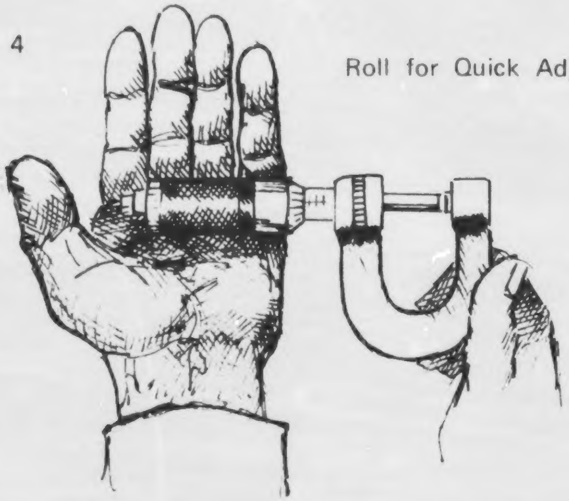
FIGURE 3


Stationary Object

JOB SHEET #13

(NOTE: Roll micrometer along palm of hand or forearm for quick adjustment. See Figure 4.)

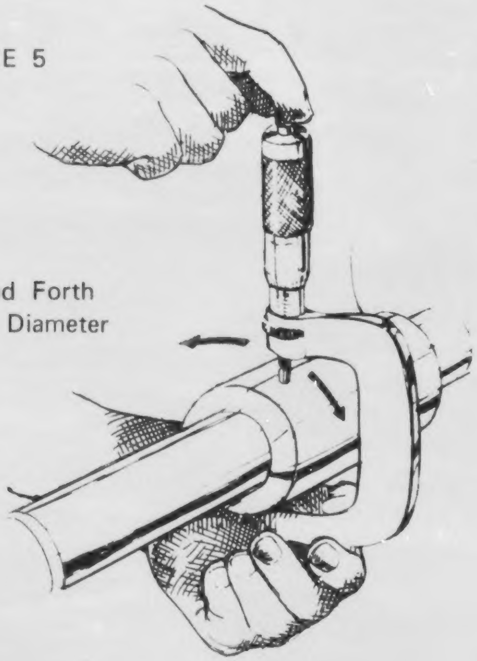
FIGURE 4



Roll for Quick Adjustment

F. Place the micrometer directly over the center of the workpiece to be measured (Figure 5)

FIGURE 5



Work Back and Forth
to Find True Diameter

JOB SHEET #13

G. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece

H. Hold the anvil steady and move the spindle lightly over the workpiece to locate the true centerline (Figure 5)

I. Use ratchet stop or light sense of feel to determine exact measurement

J. Observe micrometer readings

(NOTE: Spindle lock can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.)

K. List the readings according to the letter or number on the workpiece

L. Return the micrometer to its correct storage

(NOTE: The spindle and anvil of the micrometer should be left open when stored.)

M. Hand in the listed readings to the instructor for evaluation

BASIC SHOP TOOLS
UNIT III

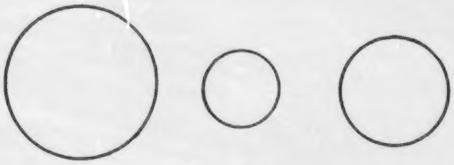
JOB SHEET #14--USE THE INSIDE MICROMETER

I. Tools and materials

  A. Various sizes of inside micrometers

  B. Different size bores (Figure 1)

  FIGURE 1



  C. Clean shop towels

II. Procedure

  A. Workpieces to be measured must be clean and free of burrs, nicks, or dents

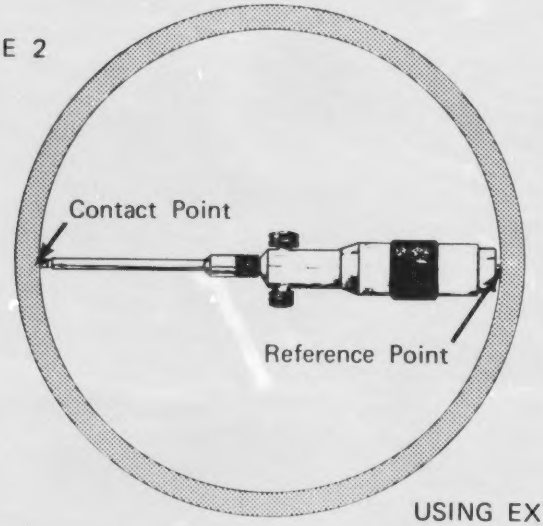
  B. Clean the contact points and accessories of the inside micrometer

  C. Select the correct extension rod and collar for the required measurement

JOB SHEET #14

D. Establish a good reference and contact point during measurement (Figure 2)

FIGURE 2



USING EXTENSION ROD AND EXTENSION COLLAR

(NOTE: Support inside micrometer in a comfortable position during use.)

E. Move the contact point from side to side ("centralize") to find the true diameter of the workpiece (Figure 2)

F. Observe the total reading from the base unit of the inside micrometer

(NOTE: Add extension rod and/or extension collar (if used) to the total measurement.)

BASIC SHOP TOOLS
UNIT III

JOB SHEET #15--USE THE DEPTH MICROMETER

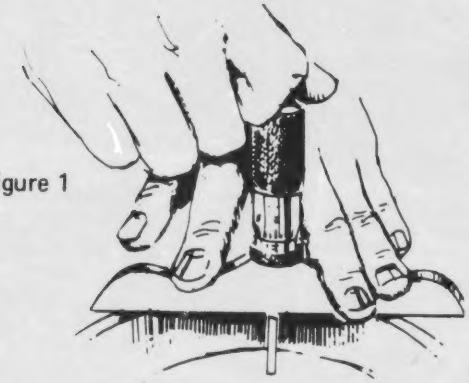
I. Tools and materials

- A. A depth micrometer set which includes extension rods
- B. Assortment of machined workpieces with grooves, slots, or shoulders
- C. Clean shop towels

II. Procedure

- A. Workpieces to be measured must be clean and free of burrs, nicks, or dents
- B. Clean the depth micrometer base and measuring rod with a clean cloth
- C. Select the correct extension rod
- D. Install the extension rod
- E. Check zero reference
- F. Place the base of the depth micrometer firmly against the surface of the workpiece (Figure 1)

Figure 1



PLACE BASE FIRMLY AGAINST WORKPIECE

JOB SHEET #15

G. Turn the thimble of the depth micrometer until the measuring rod lightly contacts the bottom of the slot or groove

H. Read the micrometer measurement

BASIC SHOP TOOLS
UNIT III

JOB SHEET #16--CUT EXTERNAL THREADS

I. Tools and materials

A. Die

B. Die stock (handle)

C. Vise

D. Flat tile

E. Cutting oil

F. Rod or stock to be threaded

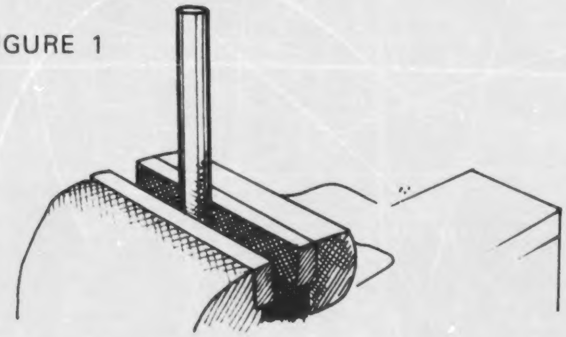
G. Shop towel

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Place rod in vise (Figure 1)

FIGURE 1



B. Chamfer end of rod with file

C. Lubricate end of rod with cutting oil

D. Place die in die stock and secure

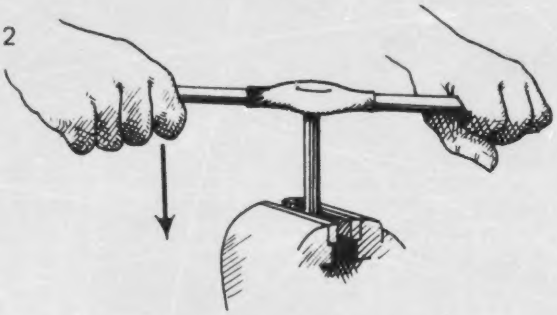
JOB SHEET #16

E. Place die on top of rod with taper facing down

F. Start die straight on the rod

G. Press down evenly and turn the die (Figure 2)

FIGURE 2



H. Apply a few drops of cutting oil while turning the die

I. Check die often for squareness

J. Turn the die one turn clockwise and then 1/4 to 1/2 a turn counterclockwise to break the chip

K. Continue this procedure until the desired amount of threads have been cut

L. Remove die by turning counterclockwise

M. Hold onto the die stock firmly while removing it so as not to drop it when it comes to the end of the threads

N. Clean threads with a brush

(CAUTION: Do not use compressed air for cleaning.)

O. Clean tools and put them away

BASIC SHOP TOOLS
UNIT III

JOB SHEET #17--CUT INTERNAL THREADS

I. Tools and materials

A. Tap

B. Tap wrench

C. Drill motor

D. Tap drill

E. Vise

F. Cutting oil

G. Stock to be drilled and threaded

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Place workpiece in vise

B. Drill hole top proper size

C. Use the chart below to select the proper tap drill

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	073	53	0 0595
2	56	086	50	0 0700
3	48	099	46	0 0810
4	40	112	43	0 0890
5	40	125	38	0 1015
6	32	138	33	0 1130
8	32	164	29	0 1360
10	24	190	25	0 1495
12	24	216	16	0 1770
1/4	20	250	7	0 2010
5/16	18	3125	F	0 2570
3/8	16	375	5/16	0 3125
7/16	14	4375	U	0 3680
1/2	13	500	27/64	0 4219
9/16	12	5625	31/64	0 4843
5/8	11	625	17/32	0 5312
3/4	10	750	21/32	0 6562
7/8	9	875	49/64	0 7656

JOB SHEET #17

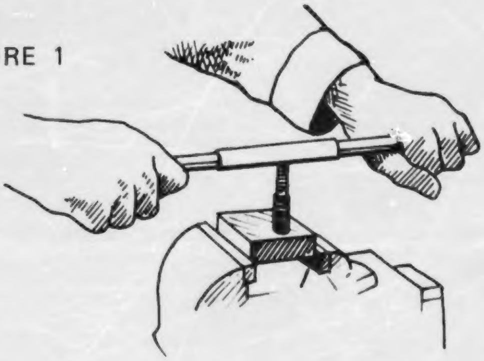
D. Place tap in tap wrench

E. Place tap in hole and keep the tap as straight as possible

F. Apply cutting oil to tap

G. Press down on tap wrench with equal pressure on both sides (Figure 1)

FIGURE 1



H. Make two complete turns with tap

I. Check to see that the tap is straight

J. If tap is not straight, remove it and restart

(NOTE: A slight amount of pressure will be required to get the tap to start straight.)

K. Tap the hole by turning the tap wrench clockwise 1/2 a turn then counterclockwise 1/4 a turn

L. After the hole is tapped, remove the tap by turning the wrench counterclockwise

(NOTE: Hold on to the tap wrench to prevent it from falling on the floor.)

M. Clean tools and put away

N. Have the instructor inspect

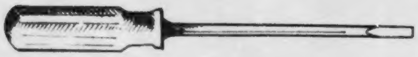
D:F - 145-A

BASIC SHOP TOOLS
UNIT III

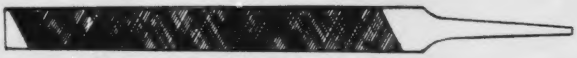
NAME ____________________

TEST

1. Identify the basic shop tools.

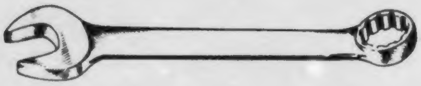


a. ____________________

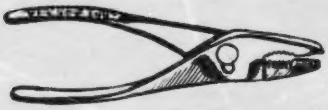


b. ____________________

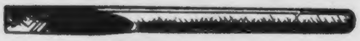
c. ____________________



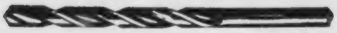
d. ____________________



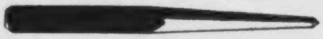
e. ____________________



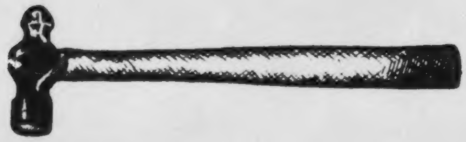
f. ____________________



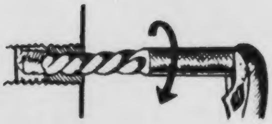
g. ____________________



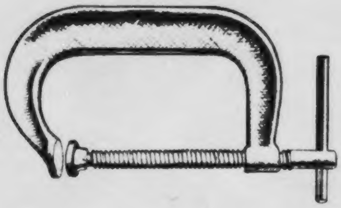
h. ____________________



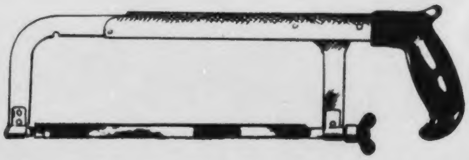
i. ______________________



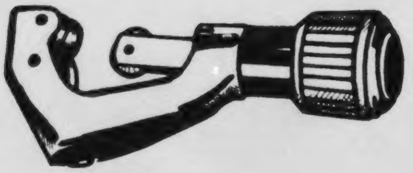
j. ______________________



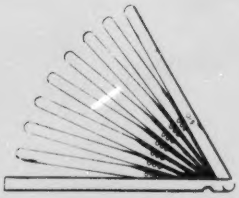
k. ______________________



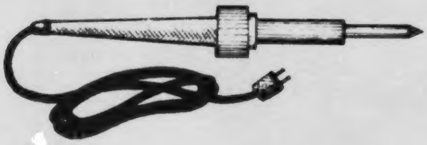
l. ______________________



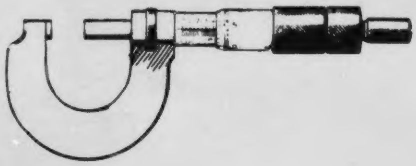
m. ______________________



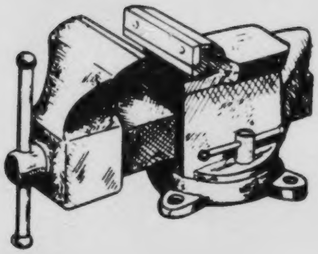
n. ______________________



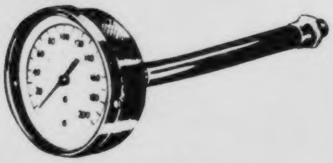
o. ______________________



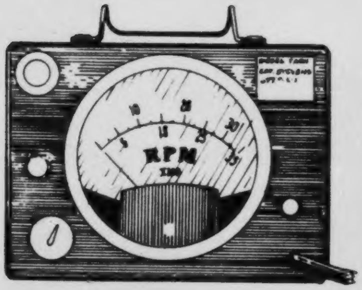
p. ______________________



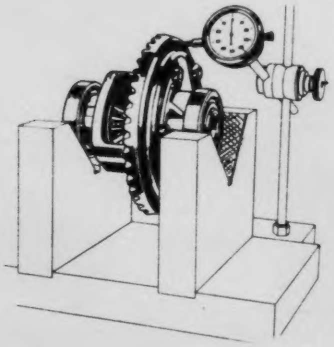
q. ______________________



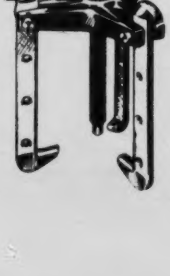
r. ______________________



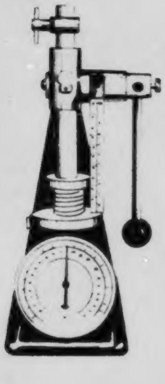
s. ______________________



t. ______________________

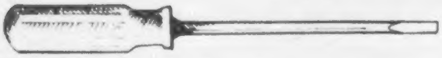


u. ______________________

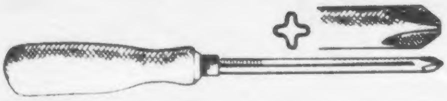


v. ______________________

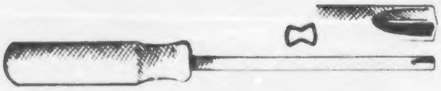
2. Identify types of screwdrivers.



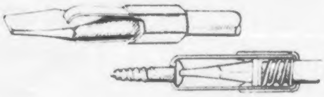
a. ____________________



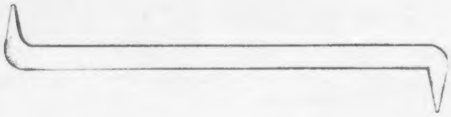
b. ____________________



c. ____________________



d. ____________________



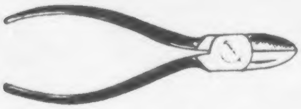
e. ____________________

3. Name two types of hammers.

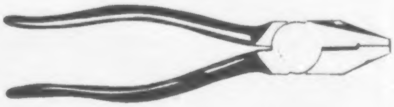
a. ____

b. ____

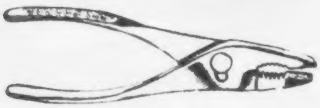
4. Identify the types of pliers.



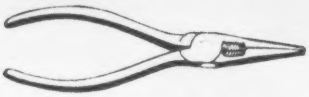
a. ____________________



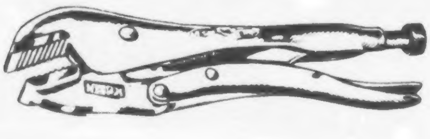
b. ____________________



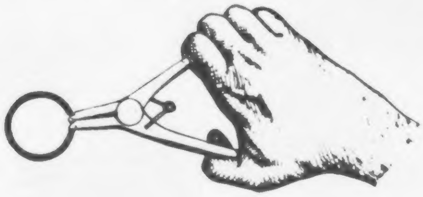
c. ______________________



d. ______________________

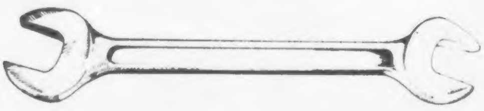


e. ______________________

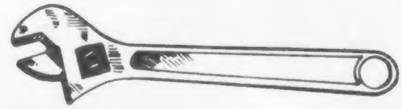


f. ______________________

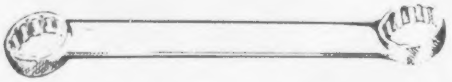
5. Identify the types of wrenches.



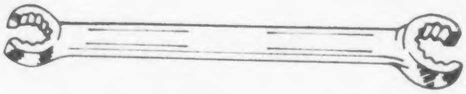
a. ______________________



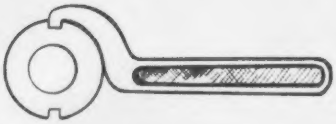
b. ______________________

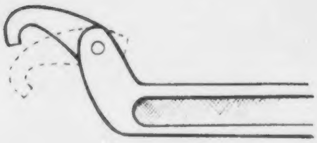


c. ______________________



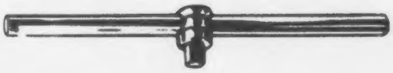
d. ______________________



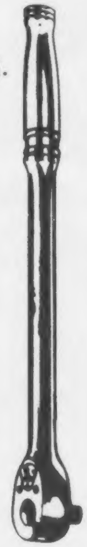


e. ____________________ f. ____________________

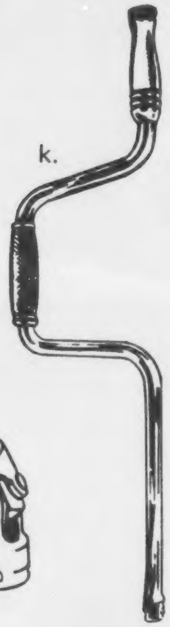
g.



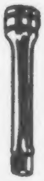
j.



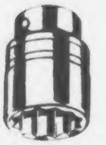
k.



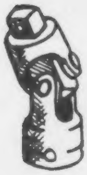
h.



i.



l.



g. ____________________

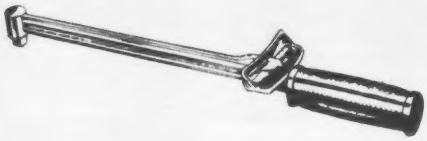
h. ____________________

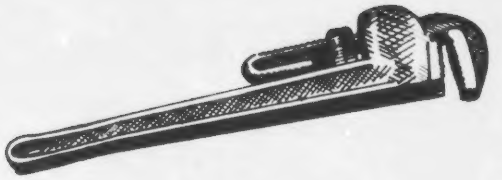
i. ____________________

j. ____________________

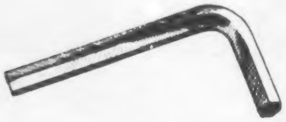
k. ____________________

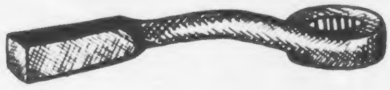
l. ____________________





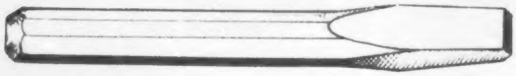
m. ______________________ n. ______________________

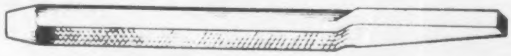




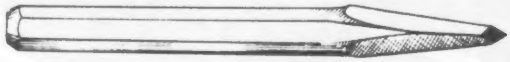
o. ______________________ p. ______________________

6. Identify the types of cold chisels.





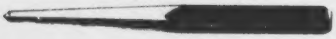
a. ______________________ b. ______________________



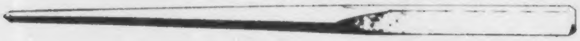
c. ______________________ d. ______________________

7. Identify the types of punches.

a. ______________________ b. ______________________

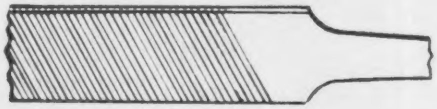


c.

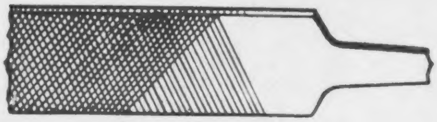


d.

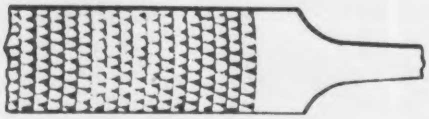
8. Identify the types of file teeth.



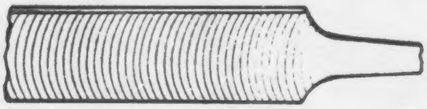
a.



b.



c.



d.

9. Name three precautions for correct use of the hacksaw.

a.

b.

c.

10. Name three principal parts of a twist drill.

a.

b.

c.

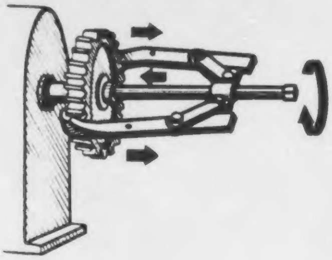
11. Name three ways to extract a screw.

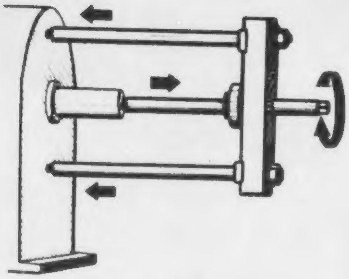
a.

b.

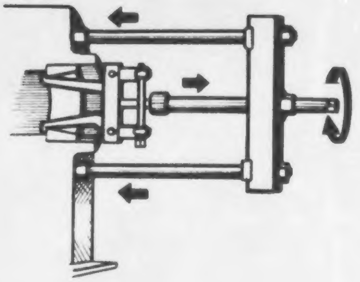
c.

12. Identify three types of pullers.





a. ______________________ b. ______________________



c. ______________________

13. Name three shop tools used for measuring speed.

a. ______________________

b. ______________________

c. ______________________

14. List two types of feeler gauges.

a. ______________________

b. ______________________

15. Name three types of taps and their functions.

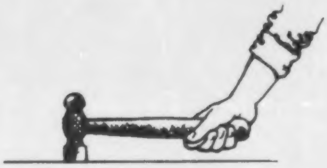
a. ______________________

b. ______________________

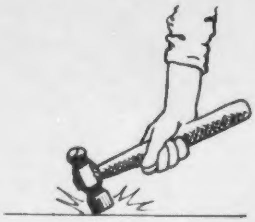
c. ______________________

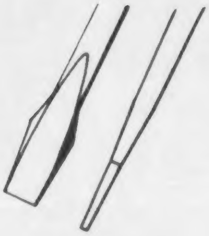
16. Distinguish between correct and incorrect methods of using and maintaining basic shop tools by placing an "X" next to the illustrations of correct methods.

_____a.

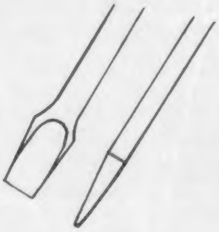


_____b.

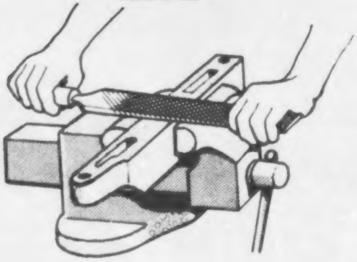




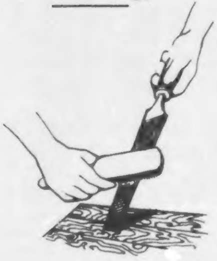
_____c.



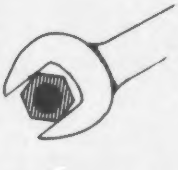
_____d.



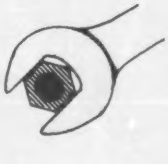
_____e.



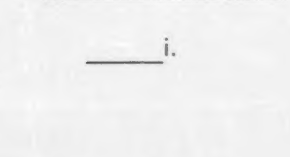
_____f.



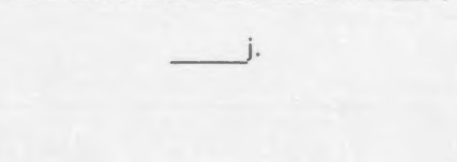
_____g.



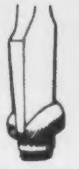
_____h.



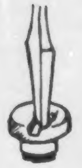
_____i.



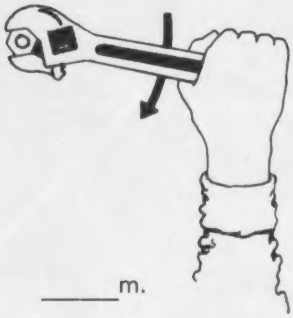
_____j.



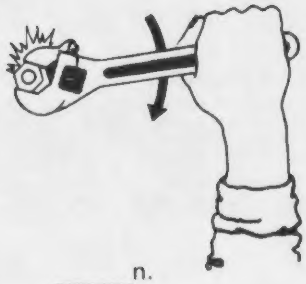
______k.



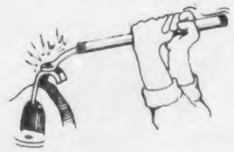
______l.



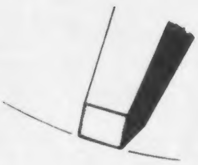
______m.



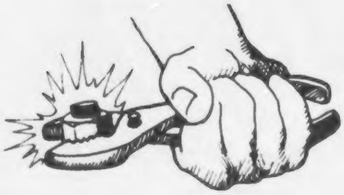
______n.



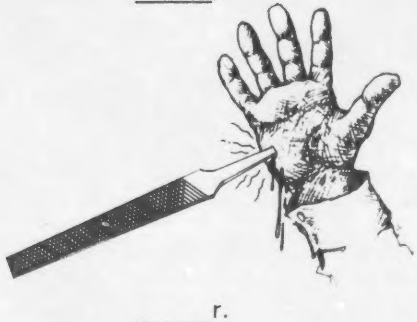
______o.



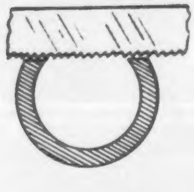
______p.



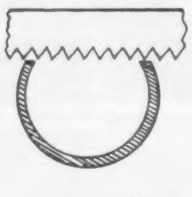
______q.



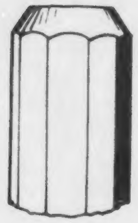
______r.



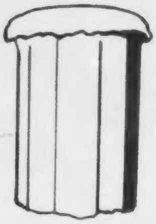
______s.



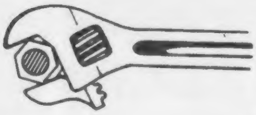
______t.



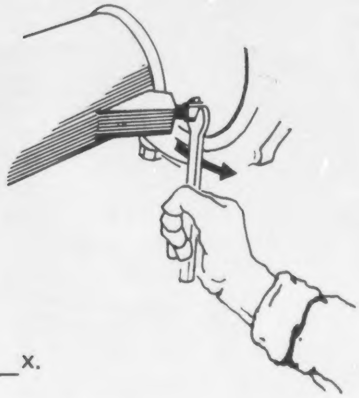
______u.



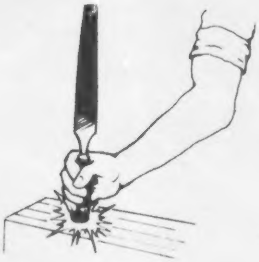
______v.



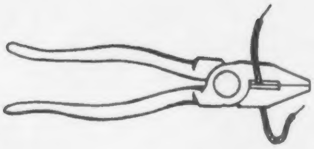
______w.



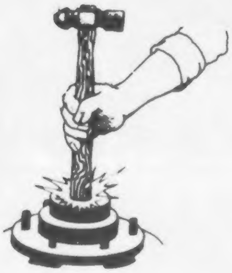
______x.



______y.



______z.



______aa.

17. Name four types of micrometers.

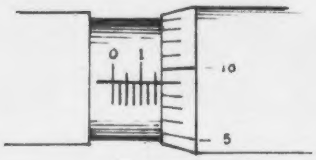
a. ______________________________

b. ______________________________

c. ______________________________

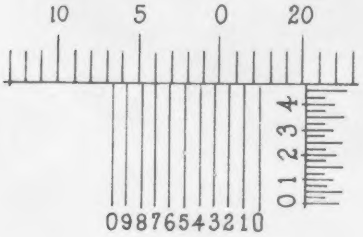
d. ______________________________

18. Read the micrometer setting.



Answer______________________

19. Read the vernier micrometer setting.


10
5
0
20
0 1 2 3 4
0 9 8 7 6 5 4 3 2 1 0

Answer______________________

20. Demonstrate the ability to:

a. Sharpen a twist drill.

b. Drill holes with a drill press.

c. Reshape a cold chisel.

d. Cut flat metal with a cold chisel.

e. Dress a grinding wheel.

f. Regrind a screwdriver.

g. Replace a hammer handle.

h. Tin a soldering iron.

i. Check a torque wrench for accuracy

j. Draw file a flat surface.

k. Draw a twist drill to correct center.

l. Use the outside micrometer.

m. Use the vernier micrometer.

n. Use the inside micrometer.

o. Use the depth micrometer.

p. Cut external threads.

q. Cut internal threads.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BASIC SHOP TOOLS
UNIT III

ANSWERS TO TEST

1. a. Common screwdriver
   b. Flat file
   c. Magnetic pick-up tool
   d. Combination box and open-end wrench
   e. Slip joint pliers
   f. Flat cold chisel
   g. Twist drill
   h. Center punch
   i. Ball peen hammer
   j. Screw extractor
   k. "C" clamp
   l. Hacksaw
   m. Tubing cutter
   n. Feeler gauge
   o. Soldering iron
   p. Outside micrometer
   q. Vise
   r. Pressure gauge (oil pressure)
   s. Tachometer
   t. Dial indicator
   u. External puller
   v. Spring tester

2. a. Common
   b. Phillips head
   c. Clutch head
   d. Starting
   e. Offset

3. a. Ball peen
   b. Soft

4. a. Diagonal cutters
   b. Side cutters
   c. Slip joint
   d. Needle nose
   e. Lock grip
   f. Snap ring

5. a. Open end
   b. Adjustable
   c. Box
   d. Tubing
   e. Hook spanner
   f. Adjustable hook spanner
   g. Sliding "T" handle
   h. Extension
   i. Socket
   j. Ratchet handle
   k. Speed handle
   l. Universal joint

- m. Torque
- n. Pipe
- o. Allen
- p. Striking

6. a. Flat
   b. Cape
   c. Round nose
   d. Diamond point

7. a. Starting
   b. Pin
   c. Center
   d. Aligning

8. a. Single cut
   b. Double cut
   c. Rasp cut
   d. Curved tooth

9. Any three of the following:

   a. Teeth must point away from handle
   b. Blade must be tightly stretched
   c. Select blade with correct number of teeth per inch for material being cut
   d. Use sufficient pressure on the forward stroke
   e. Use full length of blade on each stroke

10. a. Shank
    b. Flute
    c. Cutting edge

11. a. Screw extractor
    b. Stud puller
    c. Diamond point chisel

12. a. External
    b. Press
    c. Internal

13. a. Revolution counter
    b. Tachometer
    c. Timing light (Stroboscope)

14. a. Standard
    b. Stepped

15. a. Taper--Used to start the thread
    b. Plug--Used after taper tap has cut the threads as far as possible
    c. Bottoming--Used last to cut the thread to the bottom of the hole

16. a, c, e, f, h, i, k, m, p, s, u, x,y,z

17. a. Outside
    b. Inside
    c. Depth
    d. Vernier

18. 0.159
19. 0.4697
20. Performance skills evaluated to the satisfaction of the instructor

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify test equipment and service tools and match them to their correct functions. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with test equipment and service tools with the correct definitions.
2. Distinguish between test equipment and service tools.
3. Identify types of test equipment.
4. Identify types of service tools.
5. Match test equipment with their correct functions.
6. Match service tools with their correct functions.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate the use of test equipment.

VII. Demonstrate the use of service tools.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Test Equipment
    2. TM 2--Test Equipment (Continued)
    3. TM 3--Test Equipment (Continued)
    4. TM 4--Test Equipment (Continued)
    5. TM 5--Service Tools
    6. TM 6--Service Tools (Continued)
    7. TM 7--Service Tools (Continued)
    8. TM 8--Service Tools (Continued)
    9. TM 9--Service Tools (Continued)

D. Test

E. Answers to test

II. References:

A. *Fundamentals of Service: Engines*. 5th ed. Moline, Illinois: Deere and Company, 1980.

B. Dagel, John. F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

   A. Dynamometer--Applies a load to engine to measure horsepower and fuel consumption

   B. Manometer--Tester using mercury or water to test engine vacuums or pressures

   C. Knurl--To upset metal thereby decreasing the bore or increasing the outside diameter of a cylindrical object

   D. Ream--To enlarge or dressout a hole or bore

   E. Diagnose--To recognize by signs or symptoms

   F. Thermocouple--Two dissimilar wires joined at one end, and used to measure temperature differences

II. Function of test equipment and service tools

   A. Test equipment--To diagnose the engine

   B. Service tools--To repair the engine

III. Test equipment (Transparencies 1, 2, 3, and 4)

   A. Cylinder compression tester

   B. Cylinder bore gauge

   C. Ring groove wear gauge

   D. Piston pin bore gauge

   E. Plastigage

   F. Valve spring tester

   G. Injection nozzle tester

   H. Injection pump tester

   I. Dynamometer

   J. Manometer

INFORMATION SHEET

- K. Battery hydrometer
- L. Thermostat tester
- M. Radiator and cap tester
- N. Pyrometer

IV. Service tools (Transparencies 5, 6, 7, 8, and 9)

- A. Valve refacer
- B. Valve seat grinder
- C. Valve spring compressor
- D. Valve guide reamer
- E. Valve guide knurling tool
- F. Cylinder liner puller-installer
- G. Cylinder ridge reamer
- H. Cylinder boring bar
- I. Cylinder deglazer
- J. Piston ring groove cutting tool
- K. Piston ring expander
- L. Piston ring compressor
- M. Piston and rod aligning tool
- N. Injection nozzle removal tools
- O. Injection nozzle cleaning kit
- P. Valve seat cutter
- Q. Valve seat installer

V. Test equipment and their functions

- A. Cylinder compression tester--Measures cylinder pressure
- B. Cylinder bore gauge--Checks the roundness or taper of a cylinder
- C. Ring groove wear gauge--Measures the amount of wear in the piston ring grooves

INFORMATION SHEET

D. Piston pin bore gauge--Measures piston pin bore for precision fits

E. Plastigage--Determines engine bearing clearance

F. Valve spring tester--Checks the strength of valve springs

G. Injector nozzle tester--Checks the condition of needle valve and seat, spray pattern, cracking pressure of nozzle, leak off through nozzle, and nozzle valve lift

H. Injection pump tester--Tests and calibrates diesel fuel injection pump

(NOTE: An injection pump tester tests leakage, vacuum, pressure, and delivery used to make idle and torque control adjustments.)

I. Dynamometer--Applies a load to engine to measure engine horsepower and fuel consumption

J. Manometer--Checks the air intake system of an engine for restrictions

K. Battery hydrometer--Checks the specific gravity of a battery

L. Thermostat tester--Checks the temperature at which the thermostat starts to open

M. Radiator and cap tester--Checks the radiator and cap for leaks and correct opening pressure

N. Pyrometer--Instrument for measuring temperatures beyond the range of a mercurial thermometer

VI. Service tools and their functions

A. Valve refacer--Grinds an exact angle on the face of a valve

B. Valve seat grinder--Used to reseat valves with both rough and finishing grinding stones

C. Valve spring compressor--Compresses the spring when removing or installing the valve

D. Valve guide reamer--Reams used valve guides

(NOTE: A valve guide reamer is ideal for cleaning carbon from used guides.)

E. Valve guide knurling tool--Used to resize a worn valve guide

INFORMATION SHEET

F. Cylinder liner puller-installer--Hydraulic or manual tool used to remove or install cylinder liners

G. Cylinder ridge reamer--Removes the ring ridges found at the top of a cylinder or liner

H. Cylinder reboring bar--Used to machine the cylinders of large engines which have integral cylinders

(NOTE: The boring operation is necessary if oversized pistons are to be used.)

I. Cylinder deglazer--Used to deglaze and finish the cylinder or cylinder liner bore

(NOTE: Stone, pad, and brush types of cylinder deglazers are available.)

J. Piston ring groove cutting tool--Used to machine worn piston ring grooves

(NOTE: New standard width rings can be used with flat steel spacers after groove cutting.)

K. Piston ring expander--Used to remove or install piston rings without damage

L. Piston ring compressor--Used to compress the piston rings when installing pistons into the cylinder

M. Piston and rod aligning tool--Checks the piston and rod alignment

(NOTE: Bending bars and clamps are used to correct any bend, twist, or offset in the rod.)

N. Injection nozzle removal tools--Removal and installation kit for some injection nozzles

(NOTE: A typical kit includes hose clamp pliers, nozzle puller, bore cleaning tool, and a guide.)

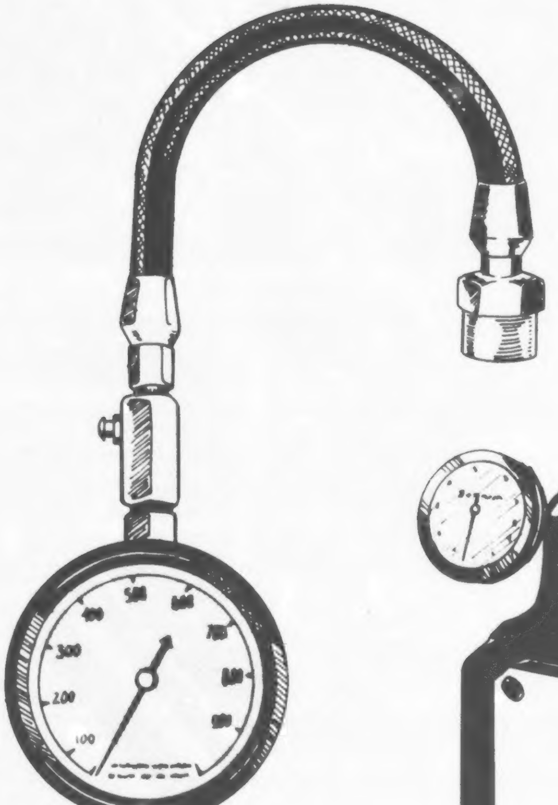
O. Injection nozzle cleaning kit--Kit of tools designed to service one particular make of nozzle

(NOTE: Kits usually include cleaning wires, brushes, drills, and lapping compounds.)

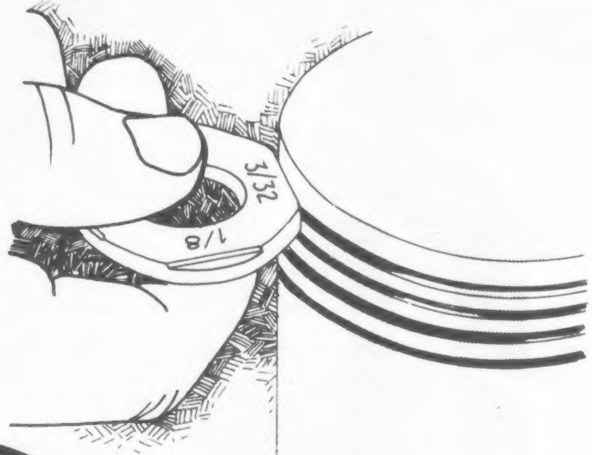
P. Valve seat cutter--Tool used to cut new angles, or dress up valve seat

Q. Valve seat installer--Tool used to install valve seat inserts in the cylinder head

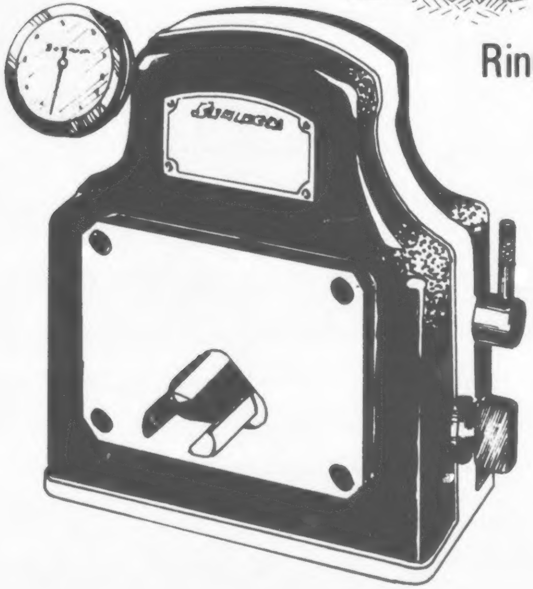
Test Equipment


100
200
300
400
500
600
700
800
900

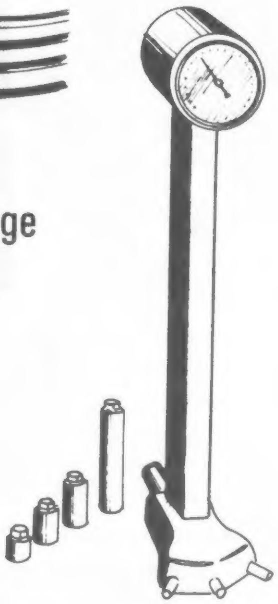
Cylinder Compression Tester



Ring Groove Wear Gauge



Piston Pin Bore Gauge



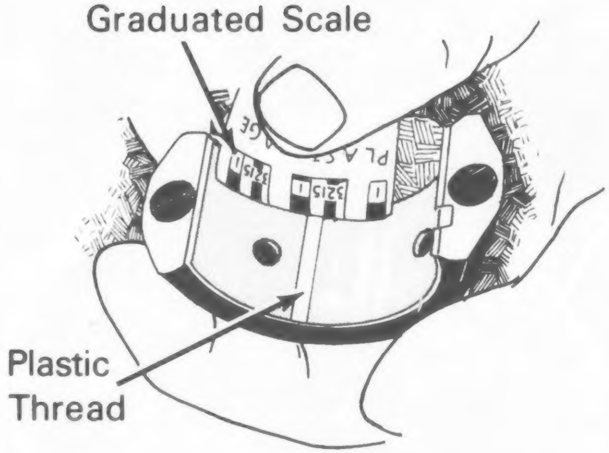
Cylinder Bore Gauge

TM 1

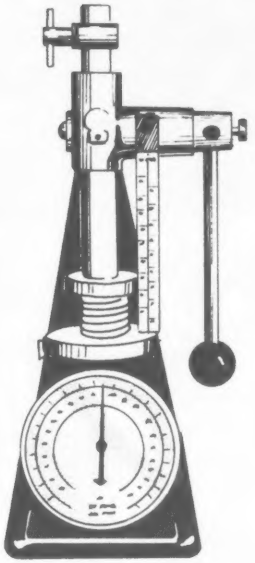
D:F - 171-A

Test Equipment

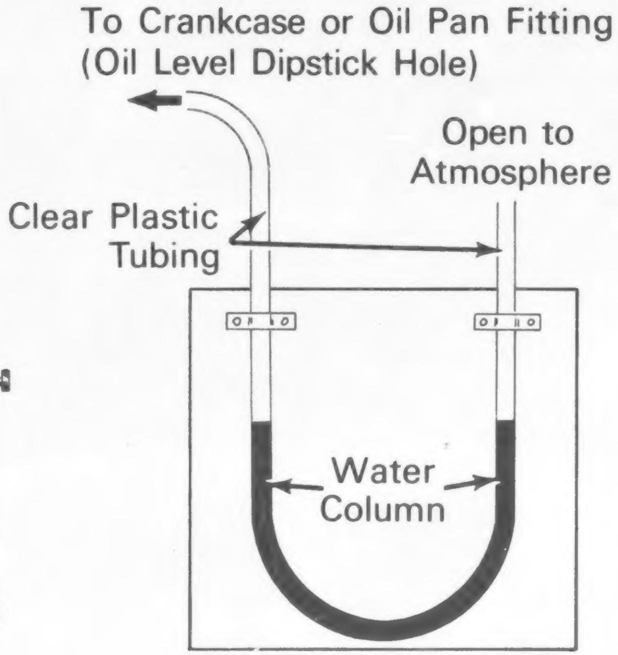
(Continued)


Graduated Scale
PLASTIGAGE
Plastic Thread

Plastigage



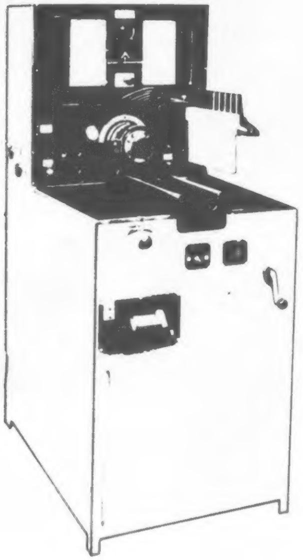
Valve Spring Tester


To Crankcase or Oil Pan Fitting (Oil Level Dipstick Hole)
Open to Atmosphere
Clear Plastic Tubing
Water Column

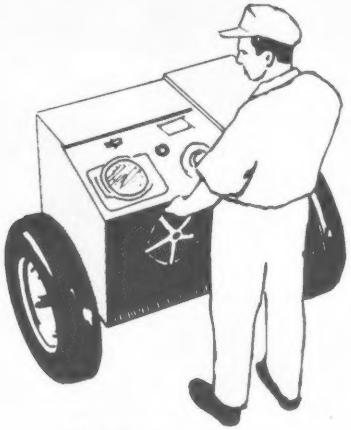
Manometer

Test Equipment

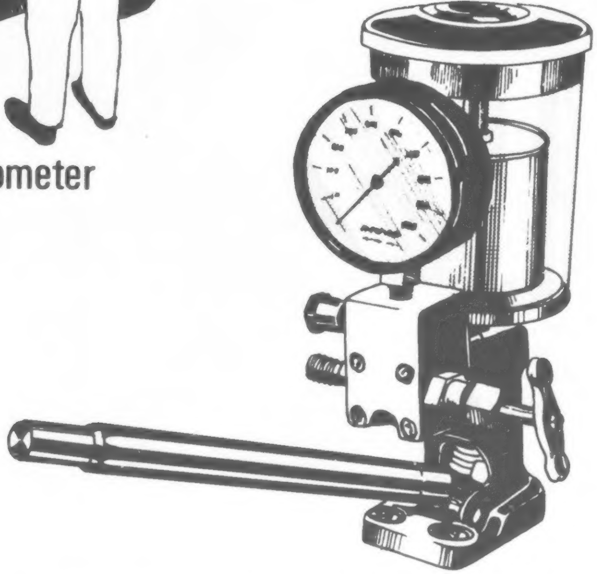
(Continued)



Injection Pump Tester



Dynamometer

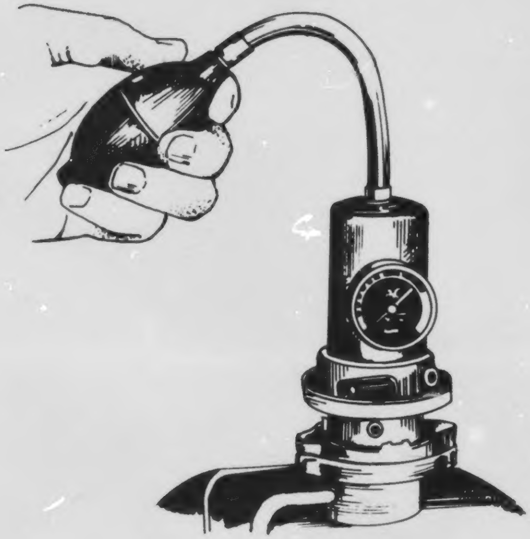


Injection Nozzle Tester (Diesel)

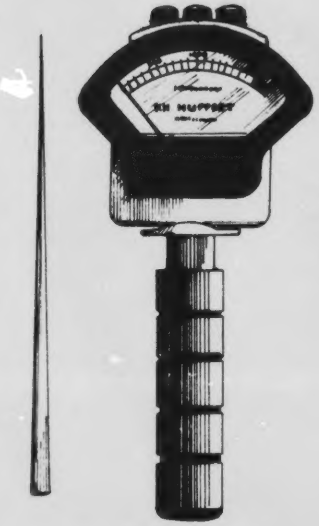
TM 3

Test Equipment

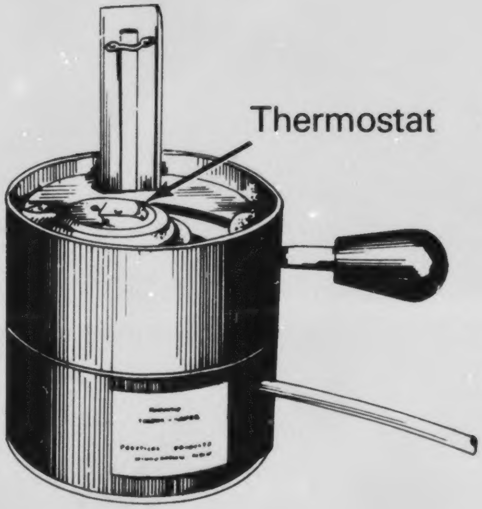
(Continued)



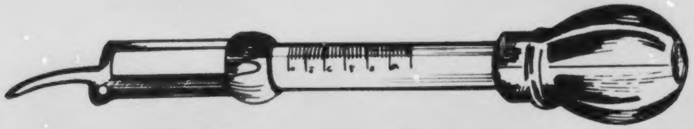
Radiator and Cap Tester



Pyrometer

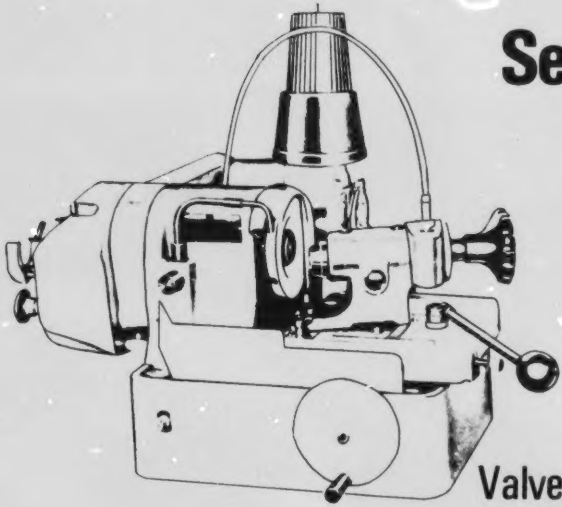


Thermostat Tester

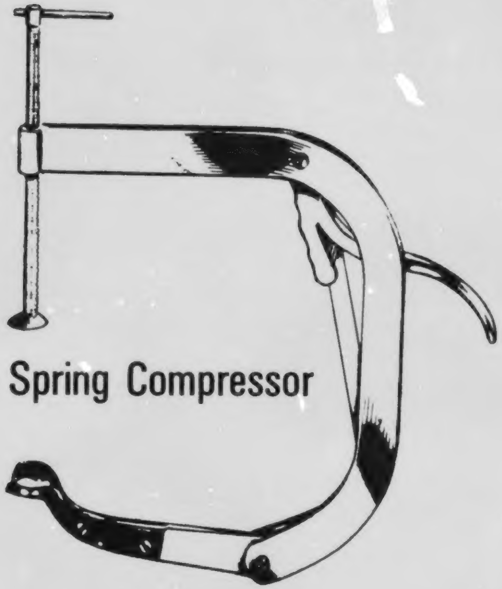


Battery Hydrometer

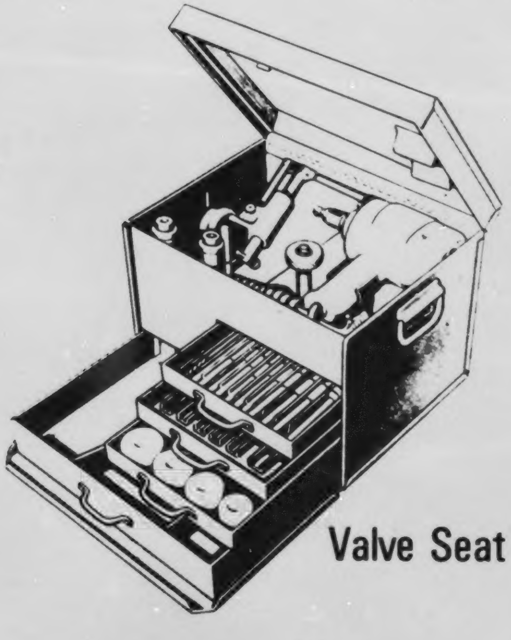
Service Tools



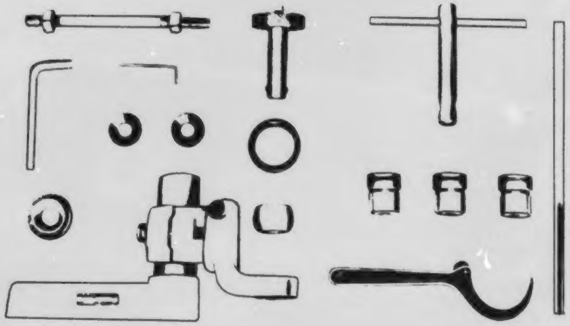
Valve Refacer



Valve Spring Compressor



Valve Seat Grinder



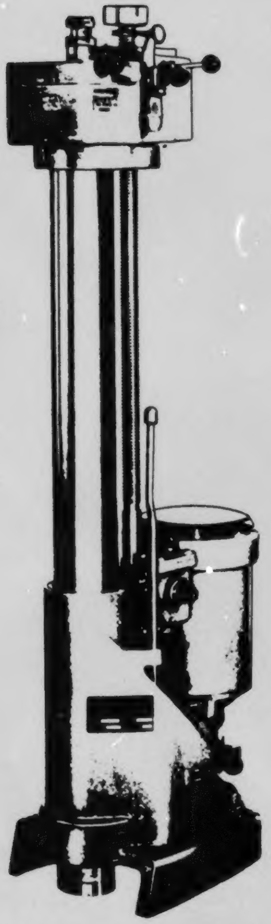
Valve Guide Reamer

191

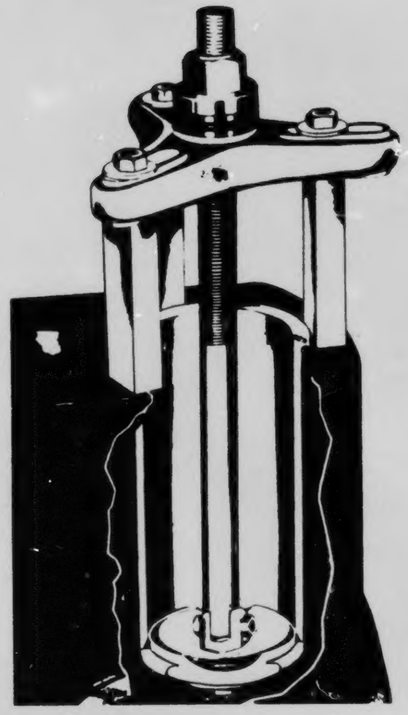
192

Service Tools

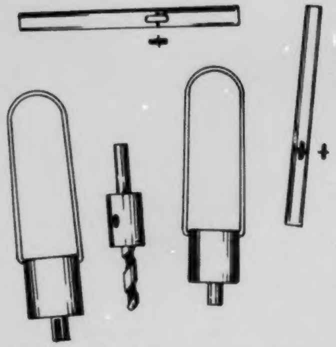
(Continued)



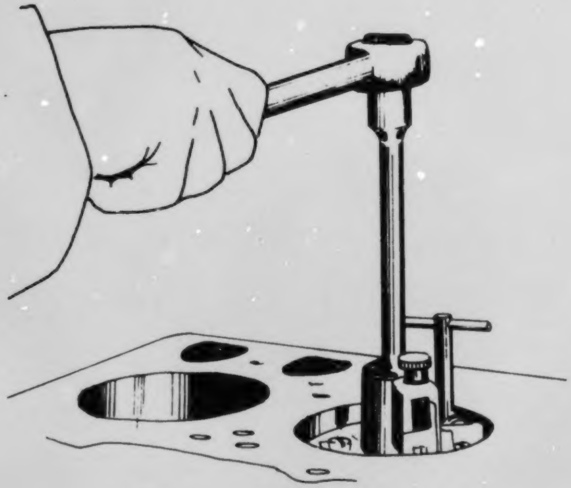
Cylinder Boring Bar



Cylinder Liner Puller-Installer



Valve Guide Knurling Tool

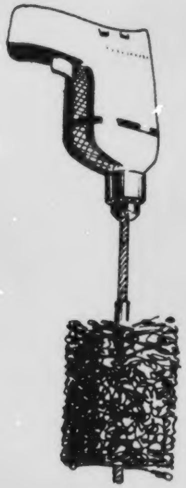


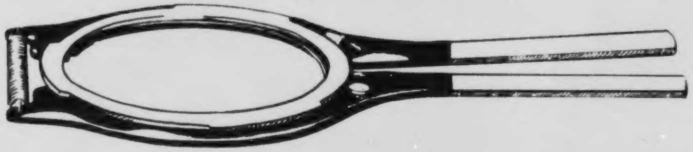
Cylinder Ridge Reamer

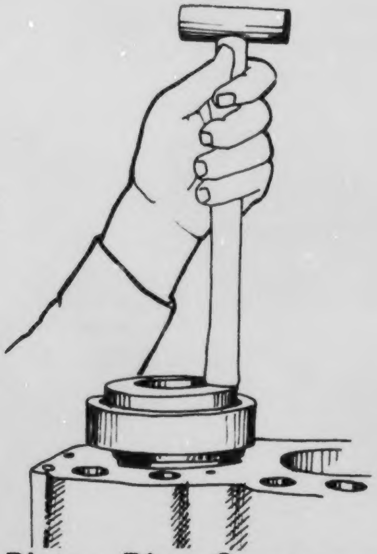
193

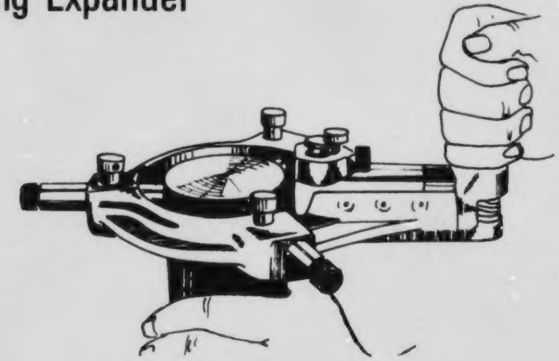
194

Service Tools
(Continued)


Cylinder Deglazer


Piston Ring Expander


Piston Ring Compressor

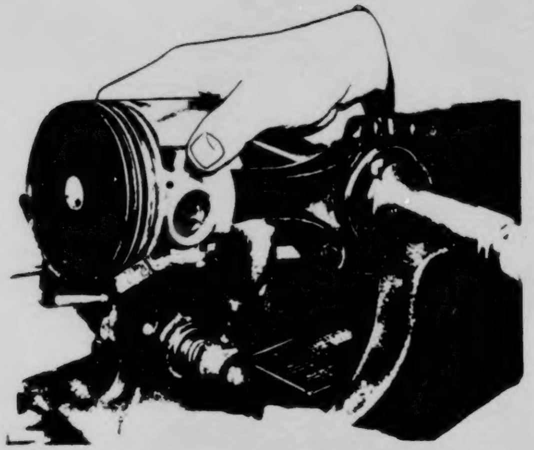

Piston Ring Groove Cutting Tool

TM 7

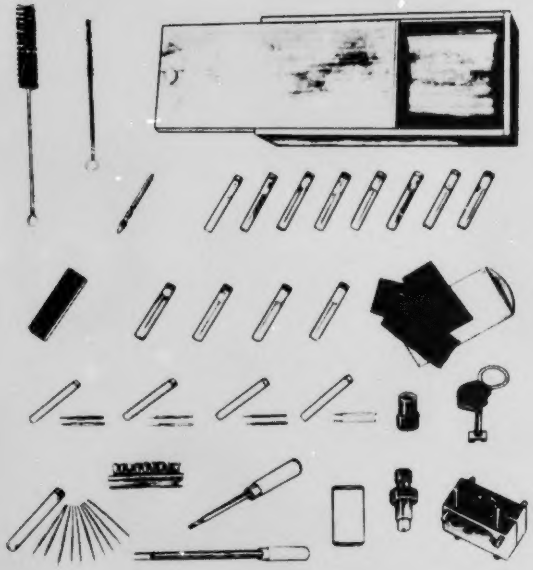
D:F - 183-A

Service Tools

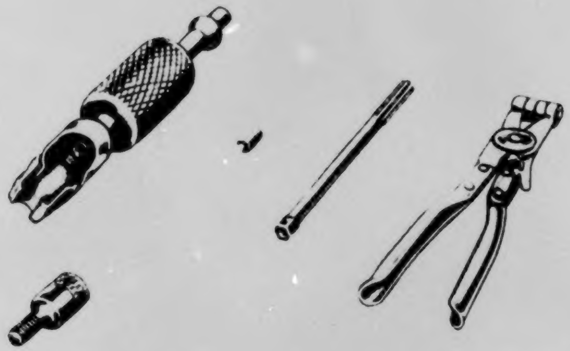
(Continued)



Piston and Rod Aligning Tool



Injection Nozzle Cleaning Kit (Diesel)

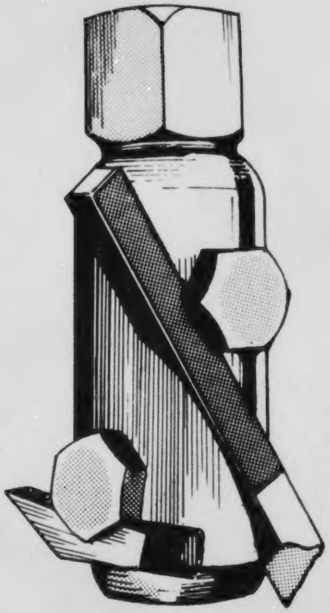


Injection Nozzle Removal Tools (Diesel)

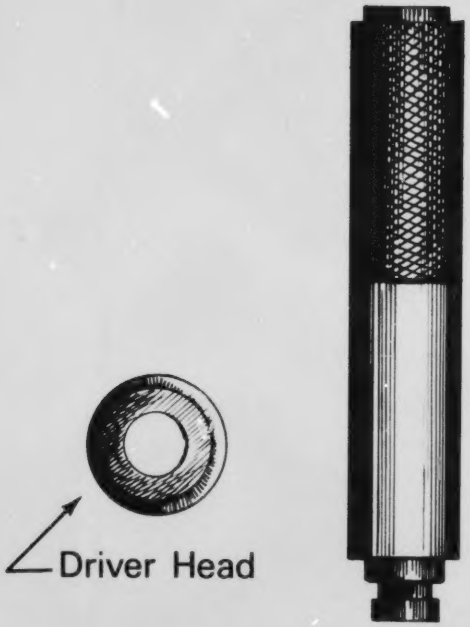
TM 8

D:F - 185-A

Service Tools
(Continued)



Valve Seat Cutter


Driver Head

Valve Seat Installer

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Applies a load to engine to measure horsepower and fuel consumption

_____b. Tester using mercury or water to test engine vacuums or pressures

_____c. To upset metal thereby decreasing the bore or increasing the outside diameter of a cylindrical object

_____d. To enlarge or dressout a hole or bore

_____e. To recognize by signs or symptoms

_____f. Two dissimilar wires joined at one end, and used to measure temperature differences

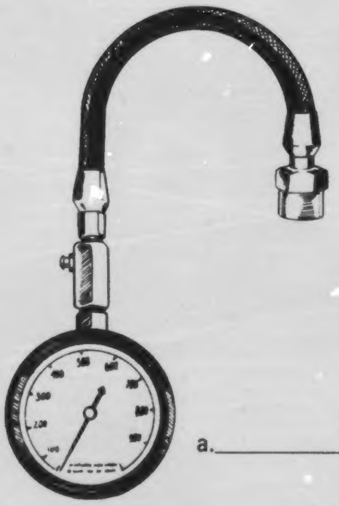
1. Manometer
2. Dynamometer
3. Diagnose
4. Knurl
5. Ream
6. Thermocouple

2. Distinguish between test equipment and service tools by placing an "X" to the left of the function of test equipment.

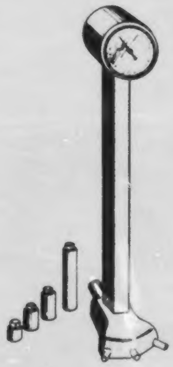
_____a. To diagnose the engine

_____b. To repair the engine

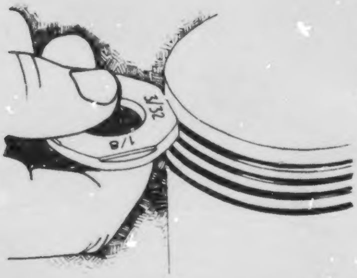
3. Identify the types of test equipment.



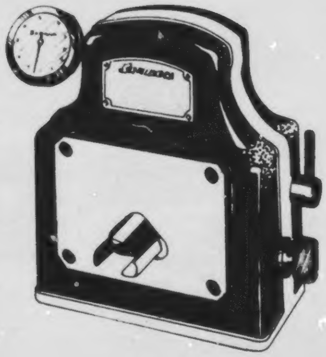
a.____________________



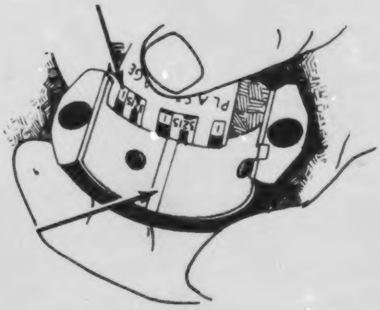
b.__________________________



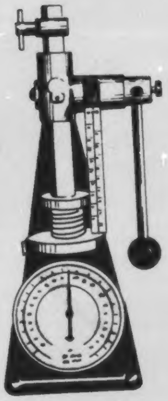
c. ______________________



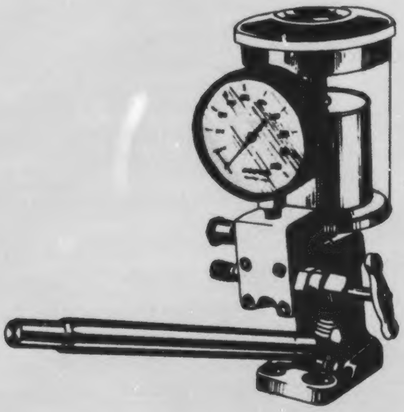
d. ______________________



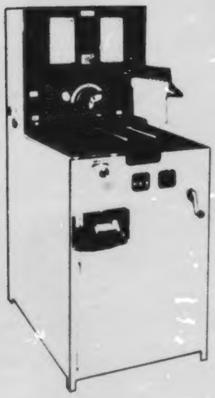
e. ______________________



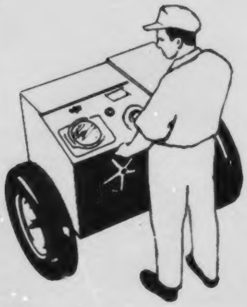
f. ______________________



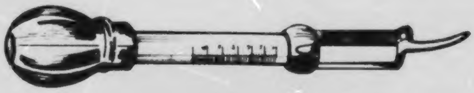
g. ______________________



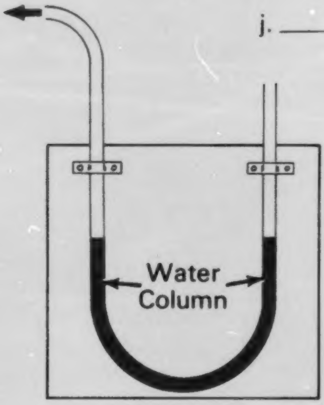
h. ______________________



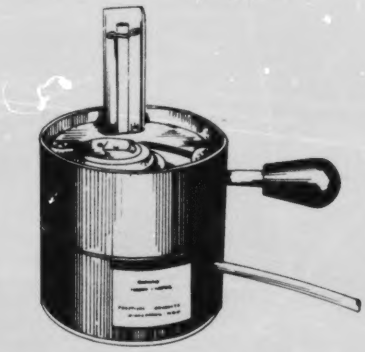
i. ______________________



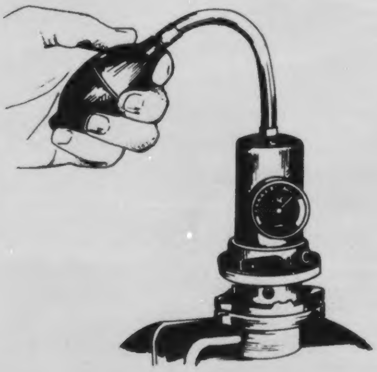
j. ______________________


Water
Column

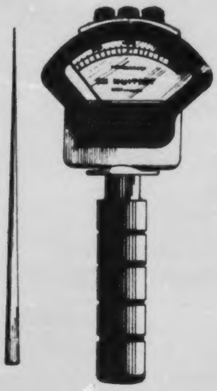
k. ______________________



l. ______________________

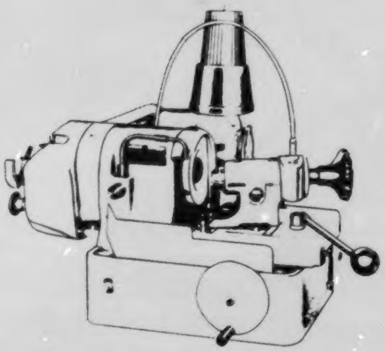


m. ______________________

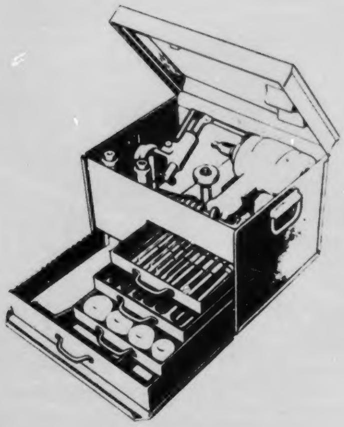


n. ______________________

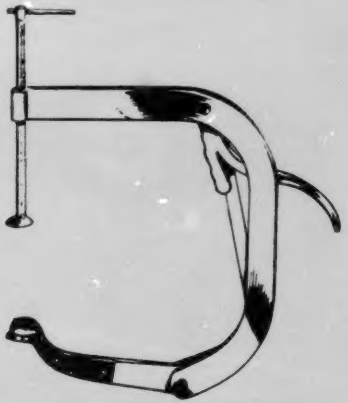
4. Identify the types of service tools.



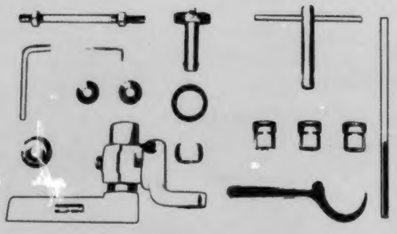
a.________________________



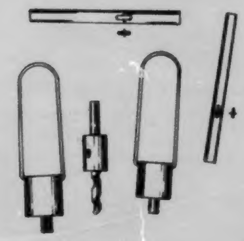
b.________________________



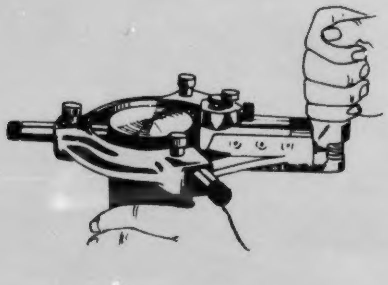
c.________________________



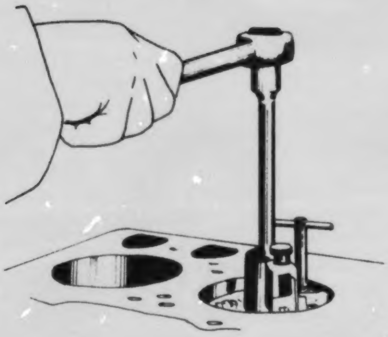
d.________________________



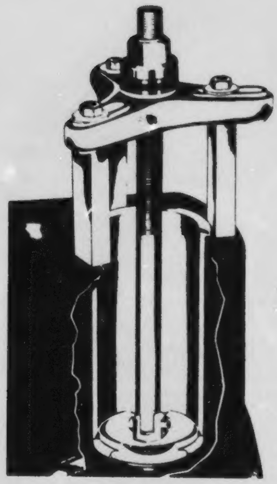
e.________________________



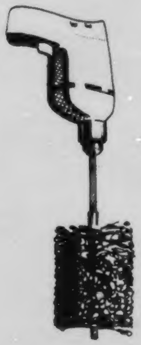
f.________________________



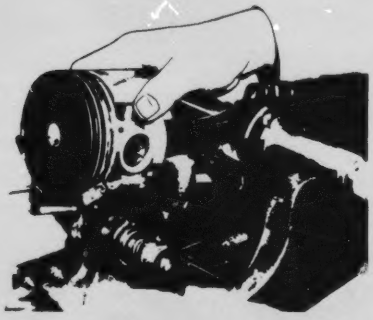
g.______________________________



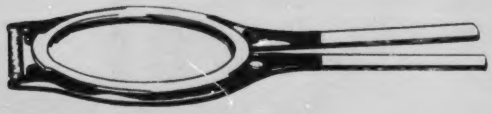
h.______________________________



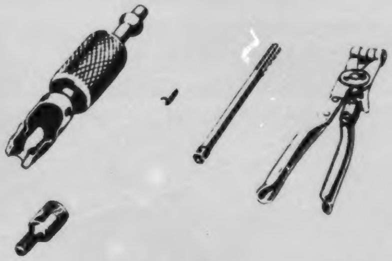
i.______________________________



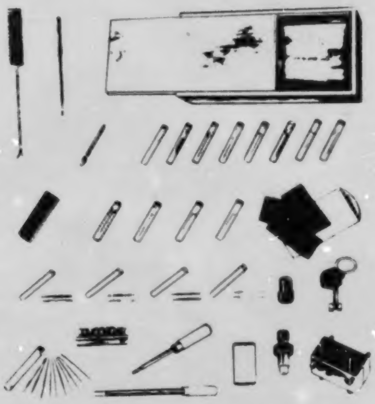
j.______________________________



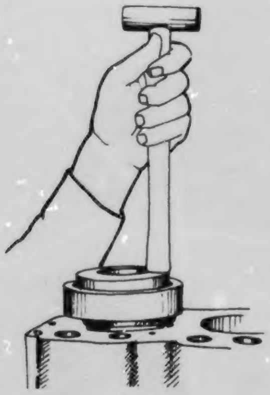
k.______________________________



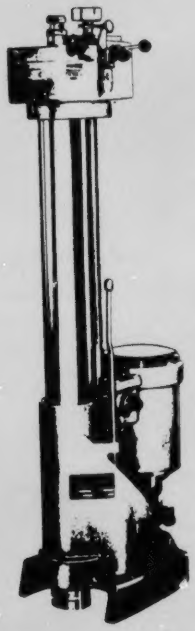
l.______________________________



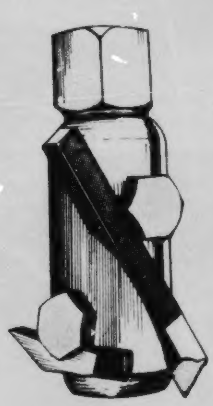
m. ______________________________



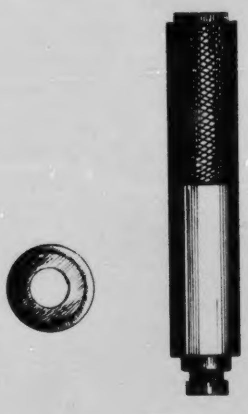
n. ______________________________



o. ______________________________



p. ______________________________



q. ______________________________

5. Match the test equipment on the right with their correct functions.

______a. Measures cylinder pressure

______b. Checks the roundness or taper of a cylinder

______c. Measures the amount of wear in the piston ring grooves

______d. Measures piston pin bore for precision fits

______e. Determines engine bearing clearance

______f. Checks the strength of valve springs

______g. Checks the condition of needle valve and seat, spray pattern, cracking pressure of nozzle, leak off through nozzle, and nozzle valve lift

______h. Tests and calibrates diesel fuel injection pump

______i. Applies a load to engine to measure engine horsepower and fuel consumption

______j. Checks the air intake system of an engine for restrictions

______k. Checks the specific gravity of a battery

______l. Checks the temperature at which the thermostat starts to open

______m. Checks the radiator and cap for leaks and correct opening pressure

______n. Instrument for measuring temperatures beyond the range of a mercurial thermometer

1. Plastigage
2. Ring groove wear gauge
3. Cylinder compression tester
4. Valve spring tester
5. Cylinder bore gauge
6. Injection nozzle tester
7. Piston pin bore gauge
8. Radiator and cap tester
9. Battery hydrometer
10. Thermostat tester
11. Dynamometer
12. Injection pump tester
13. Manometer
14. Pyrometer

6. Match the service tools on the right with their correct functions.

_____a. Grinds an exact angle on the face of a valve

_____b. Used to reseat valves with both rough and finishing grinding stones

_____c. Compresses the spring when removing or installing the valve

_____d. Reams used valve guides

_____e. Used to resize a worn valve guide

_____f. Hydraulic or manual tool used to remove or install cylinder liners

_____g. Removes the ring ridges found at the top of a cylinder or liner

_____h. Used to machine the cylinders of large engines which have integral cylinders

_____i. Used to deglaze and finish the cylinder or cylinder liner bore

_____j. Used to machine worn piston ring grooves

_____k. Used to remove or install piston rings without damage

_____l. Used to compress the piston rings when installing pistons into the cylinder

_____m. Checks the piston and rod alignment

_____n. Removal and installation kit for some injection nozzles

_____o. Kit of tools designed to service one particular make of nozzle

_____p. Tool used to cut new angles, or dress up valve seat

_____q. Tool used to install valve seat inserts in the cylinder head

1. Valve spring compressor
2. Injection nozzle cleaning kit
3. Valve seat grinder
4. Piston ring compressor
5. Valve refacer
6. Piston and rod aligning tool
7. Injection nozzle removal tools
8. Piston ring expander
9. Piston ring groove cutting tool
10. Cylinder reboring bar
11. Cylinder deglazer
12. Valve guide knurling tool
13. Cylinder liner puller-installer
14. Valve guide reamer
15. Cylinder ridge reamer
16. Valve seat installer
17. Valve seat cutter

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

ANSWERS TO TEST

1. a. 2
   b. 1
   c. 4
   d. 5
   e. 3
   f. 6

2. a.

3. a. Cylinder compression tester
   b. Cylinder bore gauge
   c. Ring groove wear gauge
   d. Piston pin bore gauge
   e. Plastigage
   f. Valve spring tester
   g. Injection nozzle tester
   h. Injection pump tester
   i. Dynamometer
   j. Battery hydrometer
   k. Manometer
   l. Thermostat tester
   m. Radiator and cap tester
   n. Pyrometer

4. a. Valve refacer
   b. Valve seat grinder
   c. Valve spring compressor
   d. Valve guide reamer
   e. Valve guide knurling tool
   f. Piston ring groove cutting tool
   g. Cylinder ridge reamer
   h. Cylinder liner puller-installer
   i. Cylinder deglazer
   j. Piston and rod aligning tool
   k. Piston ring expander
   l. Injection nozzle removal tools
   m. Injection nozzle cleaning kit
   n. Piston ring compressor
   o. Cylinder boring bar
   p. Valve seat cutter
   q. Valve seat installer

5. a. 3
   b. 5
   c. 2
   d. 7
   e. 1
   f. 4
   g. 6
   h. 12
   i. 11
   j. 13
   k. 9
   l. 10
   m. 8
   n. 14

6. a. 5
   b. 3
   c. 1
   d. 14
   e. 12
   f. 13
   g. 15
   h. 10
   i. 11
   j. 9
   k. 8
   l. 4
   m. 6
   n. 7
   o. 2
   p. 17
   q. 16

FASTENERS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify typical fasteners, discuss how bolts and threads are measured, and select qualities of satisfactory fasteners. The student should also be able to select methods used to remove seized nuts and select tools used to restore threads. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with fasteners with the correct definitions.
2. Select qualities of satisfactory fasteners.
3. Identify typical fasteners.
4. Identify typical bolt head styles.
5. Complete a list of statements concerning how bolt sizes, lengths, and threads are measured.
6. Select true statements concerning SAE grade and metric bolts.
7. Identify typical nuts.
8. Identify special purpose nuts with locking or self-locking features.
9. Select methods used to remove a seized nut.
10. Identify five types of washers.
11. Select tools used to restore bolt threads.
12. Select tools used to restore internal threads.
13. List four devices for locking nuts or bolts.
14. Identify types of machine screw head designs.
15. Identify four types of snap rings.

FASTENERS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Have students sort various nuts and bolts.

VII. Have students size different threads.

VIII. Show students various breaking points of different grade bolts.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  1. TM 1--Typical Fasteners
  2. TM 2--Bolt Head Styles
  3. TM 3--How to Measure Bolts and Threads
  4. TM 4--SAE Grade Markings for Steel Bolts and Screws
  5. TM 5--Metric Bolt and Nut Identification
  6. TM 6--Typical Nuts
  7. TM 7--Special Purpose Nuts
  8. TM 8--Methods Used to Remove a Seized Nut
  9. TM 9--Types of Washers

10. TM 10–Tools Used to Restore Bolt Threads and Internal Threads
11. TM 11--Devices for Locking Nuts or Bolts
12. TM 12–Machine Screw Head Designs
13. TM 13--Types of Snap Rings

D. Test

E. Answers to test

II. References:

A. *Fundamentals of Service: Fasteners*. 2nd ed. Moline, Illinois: Deere and Company, 1979.

B. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

FASTENERS
UNIT V

INFORMATION SHEET

I. Terms and definitions

   A. Bolt--Metal rod or pin for fastening objects together that has a head at one end, a screw thread at the other end, and is secured by a nut

   B. Screw--Pointed and headed cylindrical fastener that is threaded and designed for insertion into material by rotating

   C. Fastener--Device used to secure or hold together separate items

   D. Tap--Tool for forming an internal screw thread

   E. Die--Internally threaded screw cutting tool used for forming external screw threads

   F. Stud--Steel rod with threads on both ends, to be screwed permanently into a fixed part at one end and receive a nut on the exposed end

   G. SAE--Society of Automotive Engineers

II. Qualities of satisfactory fasteners

   A. Strong

   B. Reusable

   C. Easy to remove

   D. Withstand vibration

   E. Long lasting

   F. Corrosion resistant

   G. Temperature resistant

III. Typical fasteners (Transparency 1)

   A. Hex head bolt

   B. Wing nut

   C. Stud

   D. Woodruff key

   E. Cap screw

   F. Socket head bolt

   G. Tapping screw

INFORMATION SHEET

H. Tooth lock washer

I. Rivet

J. Bolt and nut

K. Cotter pin

L. Square key

M. Flat washer

N. Plow bolt

O. Carriage bolt

P. Castle nut

Q. Lock washer

R. Adhesive

S. Lock pin

T. Snap ring

U. Machine screw

V. Set screw

W. Spring lock pin

X. Locking nut

Y. Clevis pin

IV. Typical bolt head styles (Transparency 2)

A. Hex head bolt

B. Hex socket head bolt

C. Plow bolt

D. Square head cap screw

E. 12-point head bolt

F. Askew head bolt

G. Carriage bolt

H. Hex flange screw

INFORMATION SHEET

V. Measuring bolts and threads (Transparency 3)

- A. Size of bolt is determined by measuring the diameter of the thread end
- B. Length of bolt is determined by measuring the distance from bottom of the head to the end of the threads

  (NOTE: Some carriage bolts with round, flat, tapered heads are measured from the top of the head to the end of the threads.)
- C. Number of threads per inch is determined by measuring with a rule or a thread gauge

  (NOTE: American National Standards established the unified screw thread standard. Course threads are U.S. standard and fine threads are S.A.E. threads.)

VI. SAE grade and metric bolts (Transparencies 4 and 5)

- A. SAE grade and metric bolts are identified by markings on the heads of the bolt
- B. SAE grade bolts use slashes for identification

  Example: Grade 1 and 2 – No slashes
  Grade 5 – Three slashes
  Grade 7 – Five slashes
  Grade 8 – Six slashes
- C. Metric bolts use numbers for identification which correspond to bolt strength; increasing numbers represent increasing strength

VII. Typical nuts (Transparency 6)

- A. Acorn
- B. Castle
- C. Spring
- D. Wing
- E. Hex
- F. Flanged
- G. Lock
- H. Slotted
- I. Weld
- J. Panel
- K. Serrated

INFORMATION SHEET

L. Single thread

M. Specialty

VIII. Special purpose nuts with locking or self-locking features (Transparency 7)

A. Prevailing torque lock nut

B. Plastic insert lock nut

C. Jam nut

D. Castle nut

E. Slotted nut

F. Wing nut

G. Speed nut

H. Anchor nut

I. Chamfered nut

J. Cap nut

K. Flange-lock nut

L. Pal nut

IX. Methods used to remove a seized nut (Transparency 8)

A. Penetrating oil

B. Hacksaw

C. Nut splitter

D. Chisel

E. Gas torch

X. Types of washers (Transparency 9)

A. Flat washer

B. Lock washer

C. External toothed lock washer

D. Internal toothed lock washer

E. Countersunk external toothed washer

INFORMATION SHEET

XI. Tools used to restore bolt threads (Transparency 10)

- A. Rethreading tool
- B. Thread restorer
- C. Rethreading die

XII. Tools to restore internal threads (Transparency 10)

- A. Internal thread chaser
- B. Hand tap

XIII. Devices for locking nuts or bolts (Transparency 11)

- A. Cotter pins
- B. Lock wire
- C. Flat metal locks
- D. Lock ears

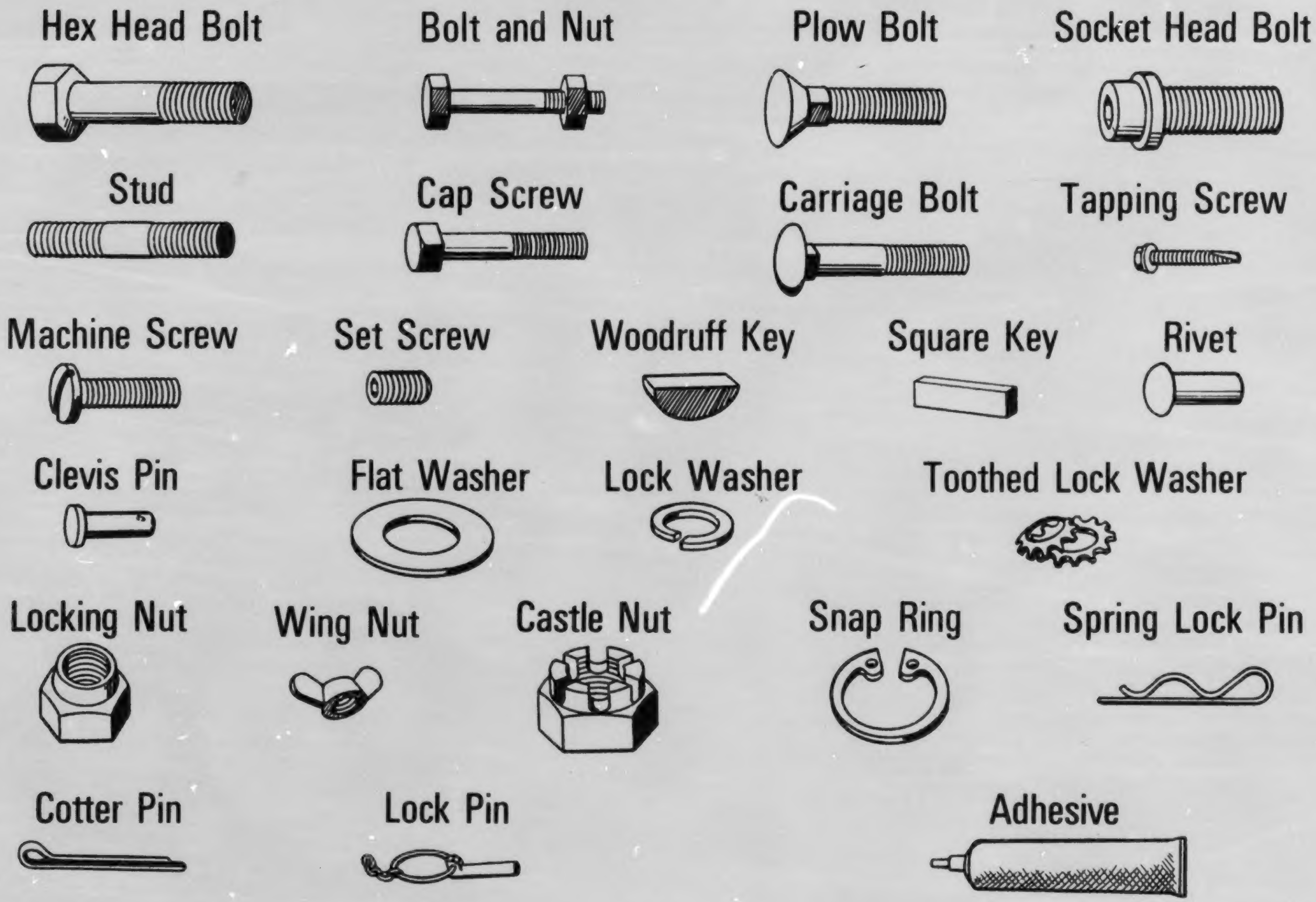
XIV. Types of machine screw head designs (Transparency 12)

- A. Round
- B. Fillister
- C. Truss
- D. Pan
- E. Oval
- F. Cross recessed or phillips
- G. Flat
- H. Clutch
- I. Hex slotted

XV. Types of snap rings (Transparency 13)

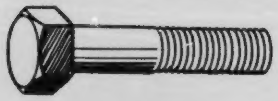
- A. Internal prong
- B. Internal hole
- C. External hole
- D. External "E"

Typical Fasteners

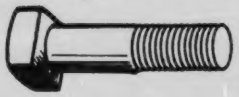

Hex Head Bolt
Bolt and Nut
Plow Bolt
Socket Head Bolt
Stud
Cap Screw
Carriage Bolt
Tapping Screw
Machine Screw
Set Screw
Woodruff Key
Square Key
Rivet
Clevis Pin
Flat Washer
Lock Washer
Toothed Lock Washer
Locking Nut
Wing Nut
Castle Nut
Snap Ring
Spring Lock Pin
Cotter Pin
Lock Pin
Adhesive

Bolt Head Styles

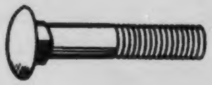
Hex Head Bolt



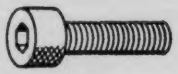
Square Head Cap Screw



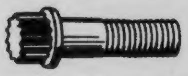
Carriage Bolt



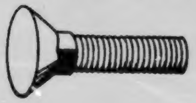
Hex Socket Head Bolt



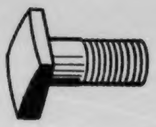
12-Point Head Bolt



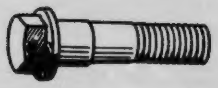
Plow Bolt



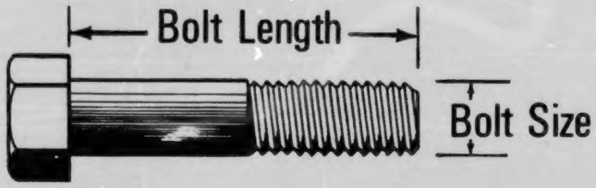
Askew Head Bolt



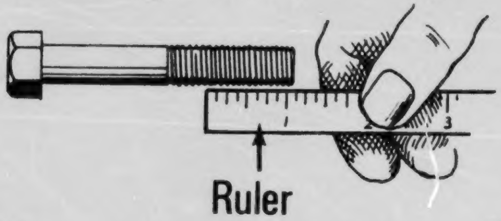
Hex Flange Screw

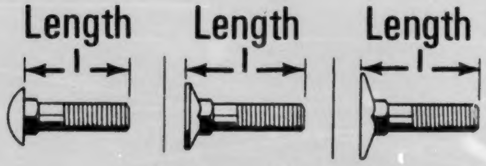


How to Measure Bolts and Threads

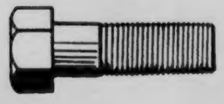

Bolt Length
Bolt Size

Measuring Threads Per Inch

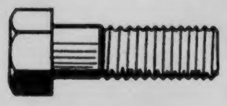



Length
l
Length
l
Length
l

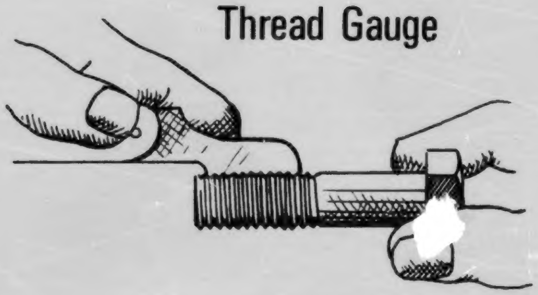
Fine Thread



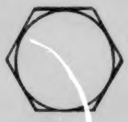
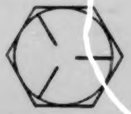
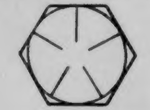
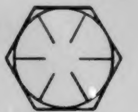
Coarse Thread



Thread Gauge

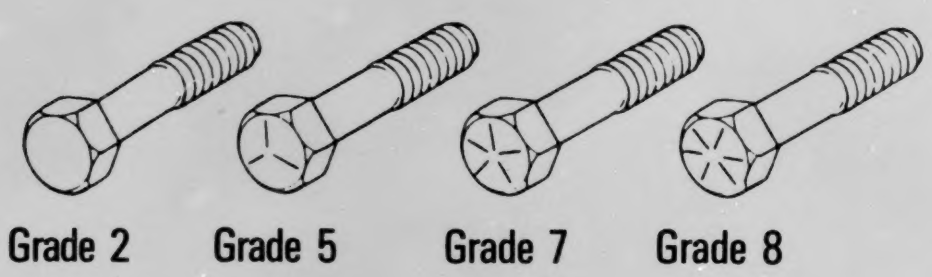


SAE GRADE MARKINGS
FOR STEEL BOLTS AND SCREWS

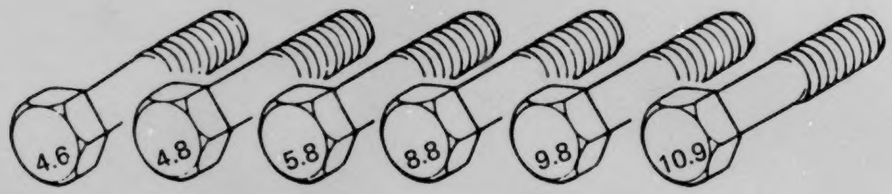
Grade Marking	Specification	Material	Tensile Strength min., psi.
	SAE-Grade 0	Steel	
	SAE-Grade 1	Low Carbon Steel	55,000
	SAE-Grade 2	Low Carbon Steel	69,000
	SAE-Grade 5	Medium Carbon Steel, Quenched and Tempered	120,000
	SAE-Grade 7	Medium Carbon Steel, Quenched and Tempered	133,000
	SAE-Grade 8	Med. Carbon Alloy Steel, Quenched and Tempered	150,000

Metric Bolt and Nut Identification

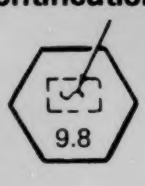
SAE Grade Bolts


Grade 2
Grade 5
Grade 7
Grade 8

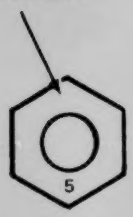
Metric Bolts


4.6
4.8
5.8
8.8
9.8
10.9

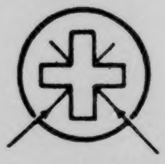
Manufacturer's Identification



Nut Strength Identification

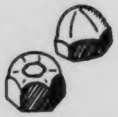


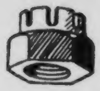
Posidriv Screw Head

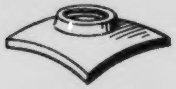


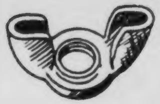
Identification Marks (4)

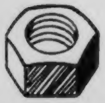
Typical Nuts

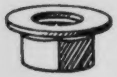

Acorn

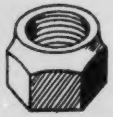

Castle

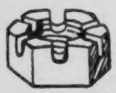

Spring

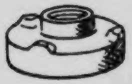

Wing

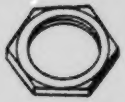

Hex

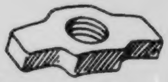

Flanged

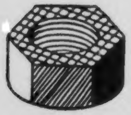

Lock

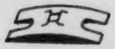

Slotted


Weld


Panel

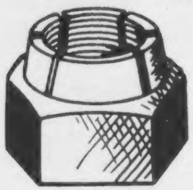

Specialty


Serrated

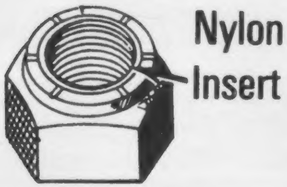

Single Thread

Special Purpose Nuts

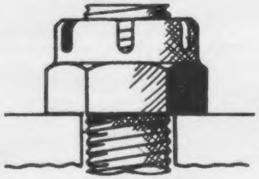
Prevailing Torque Lock Nut



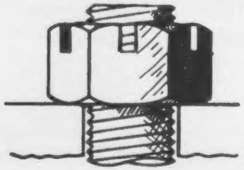
Plastic Insert Lock Nut



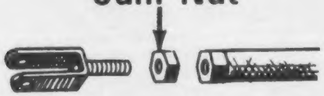
Castle Nut



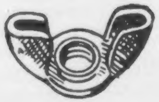
Slotted Nut



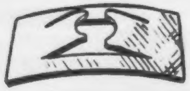
Jam Nut



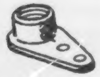
Wing Nut



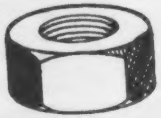
Speed Nut



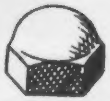
Anchor Nut



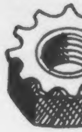
Chamfered Nut (Both Sides)



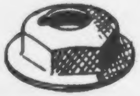
Cap Nut



Flange-Lock Nut



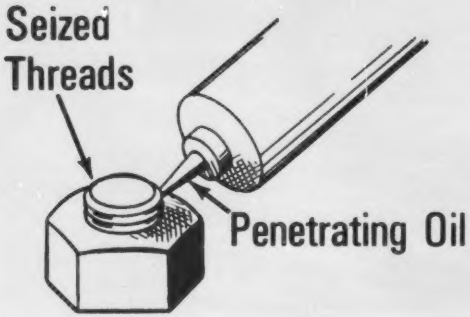
Pal Nut

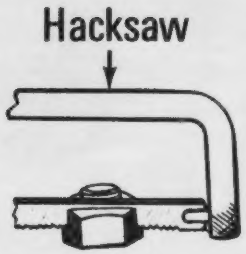


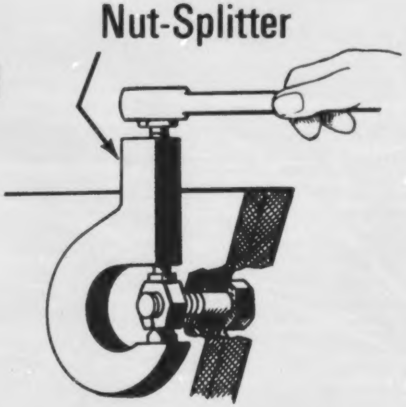
TM 7

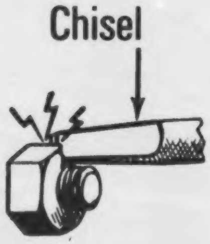
D:F - 221-A

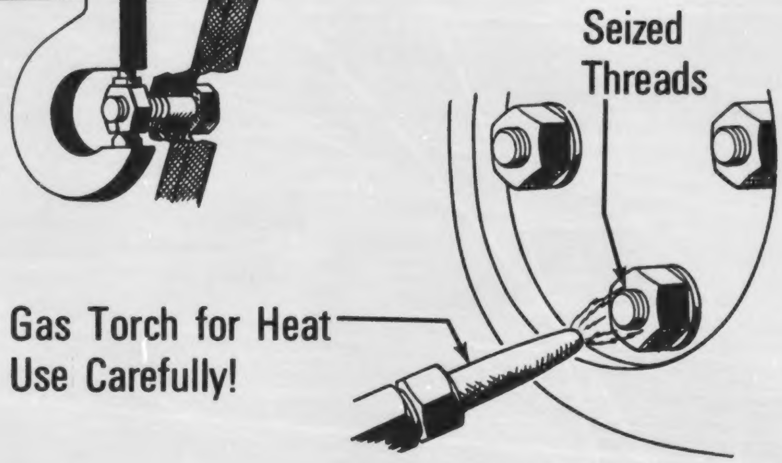
Methods Used to Remove a Seized Nut


Seized Threads
Penetrating Oil



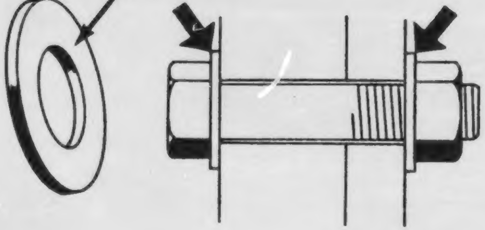

Nut-Splitter



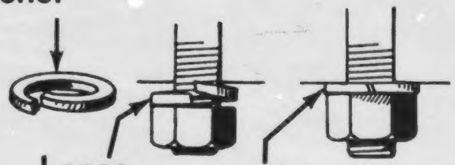

Seized Threads
Gas Torch for Heat
Use Carefully!

Types of Washers

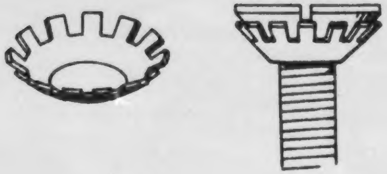
Flat Washer



Lock Washer

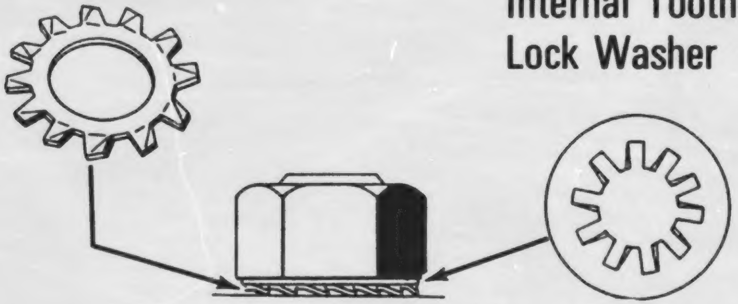

Loose
Tight
(Washer Grips)

Countersunk
External Toothed Washer



External Toothed
Lock Washer

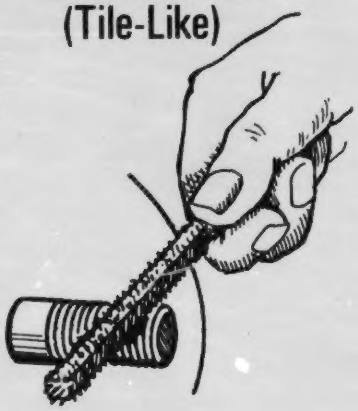
Internal Toothed
Lock Washer



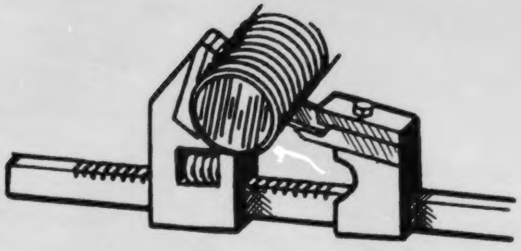
Tools Used to Restore Bolt Threads and Internal Threads

Bolt Threads

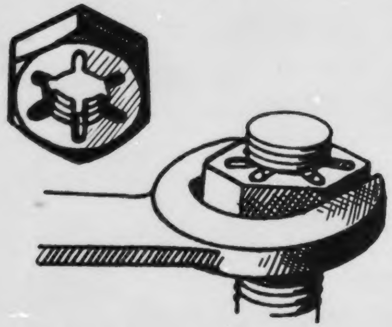
Thread Restorer (Tile-Like)



Rethreading Tool

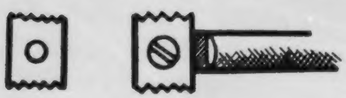


Rethreading Die

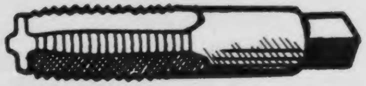


Internal Theads

Internal Thread Chasers



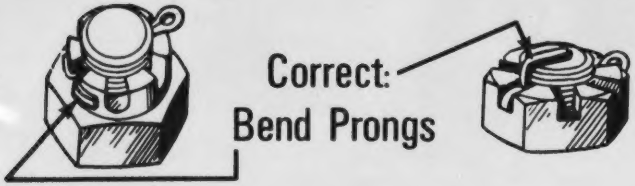
Hand Tap



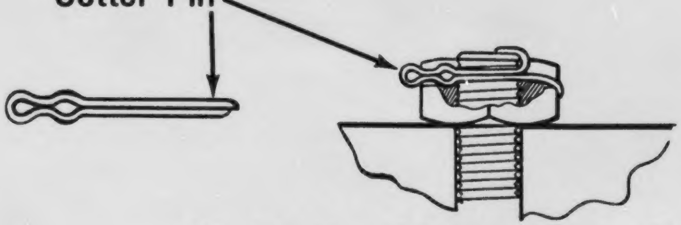
TM 10

D:F - 227-A

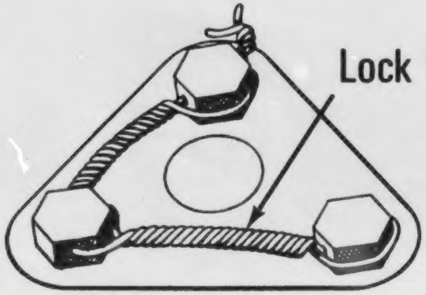
Devices for Locking Nuts or Bolts

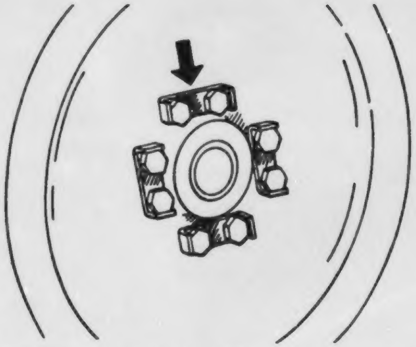

Castle Nut
Slotted Nut
Correct:
Bend Prongs

Cotter Pin Prongs Properly Bent Around Castle Nut and a Slotted Nut



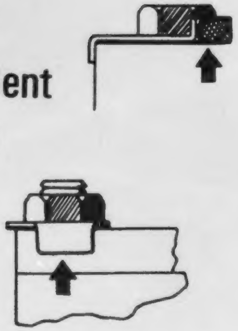
Double-Head Cotter Pin in Use





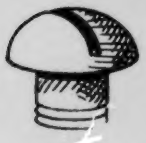
Flat Metal Locks Hold Flywheel Bolts in Place

Lock Ears Properly Bent Into Place

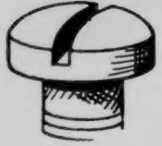


Machine Screw Head Designs

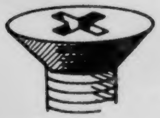
Round



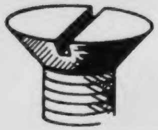
Fillister



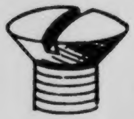
Cross Recessed
or Phillips



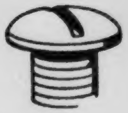
Flat



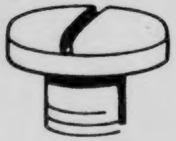
Oval



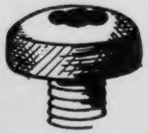
Truss



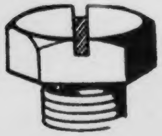
Pan



Clutch



Hex Slotted

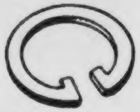


TM 12

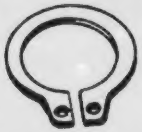
D:F - 231-A

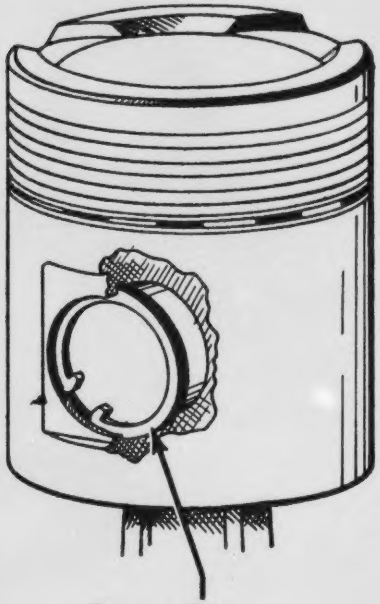
Types of Snap Rings

Internal Prong

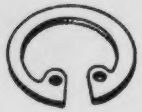


External Hole

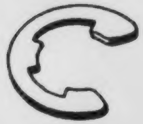




Internal Hole



External "E"



FASTENERS
UNIT V

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Metal rod or pin for fastening objects together that has a head at one end, a screw thread at the other end, and is secured by a nut

_____b. Pointed and headed cylindrical fastener that is threaded and designed for insertion into material by rotating

_____c. Device used to secure or hold together separate items

_____d. Internally threaded screw cutting tool used for forming external screw threads

_____e. Tool for forming an internal screw thread

_____f. Steel rod with threads on both ends, to be screwed permanently into a fixed part at one end and receive a nut on the exposed end

_____g. Society of Automotive Engineers

1. Tap
2. Stud
3. Screw
4. Die
5. Fastener
6. Bolt
7. SAE

2. Select qualities of satisfactory fasteners by placing an "X" in the appropriate blanks.

_____a. Easy to remove

_____b. Must be used with two washers

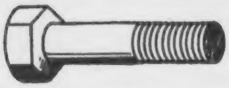
_____c. Strong

_____d. Temperature resistant

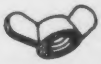
_____e. Be threaded on both ends

_____f. Reusable

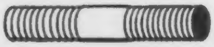
3. Identify the typical fasteners.



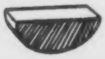
a. ____________________



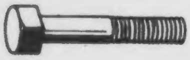
b. ____________________



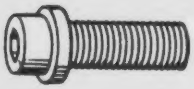
c. ____________________



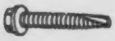
d. ____________________



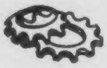
e. ____________________



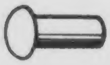
f. ____________________



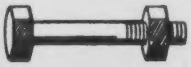
g. ____________________



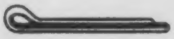
h. ____________________



i. ____________________

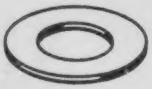


j. ____________________

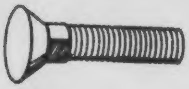


k. ____________________

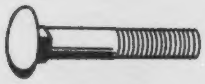
l. ____________________



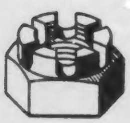
m. ____________________



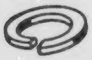
n. ____________________



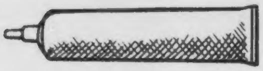
o. ____________________



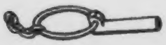
p. ____________________



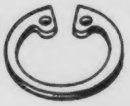
q. ____________________



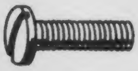
r. ____________________



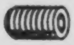
s. ____________________



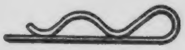
t. ____________________



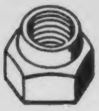
u. ____________________



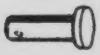
v. ____________________



w. ____________________

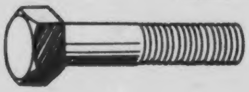


x. ____________________

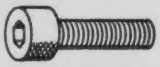


y. ____________________

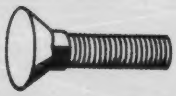
4. Identify the typical bolt head styles.

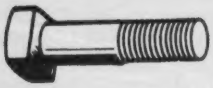


a. ____________________

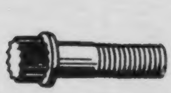


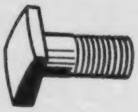
b. ____________________



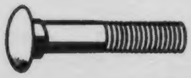


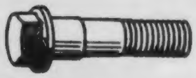
c. ______________________________ d. ______________________________





e. ______________________________ f. ______________________________





g. ______________________________ h. ______________________________

5. Complete the following list of statements concerning how bolt sizes, lengths, and threads are measured.

   a. Size of bolt is determined by measuring the diameter of the thread end

   b. Length of bolt is determined by measuring the distance from bottom of the head to the end of the threads

   c. ____

   ____

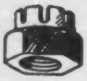
6. Select true statements concerning SAE grade and metric bolts by placing an "X" in the appropriate blanks.

   ______a. SAE grade and metric bolts are identified by markings on the heads of the bolt

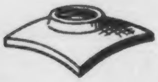
   ______b. Metric bolts use slashes for identification

   ______c. SAE grade bolts use numbers for identification which correspond to bolt strength; increasing numbers represent increasing strength

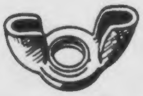
7. Identify the typical nuts.



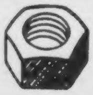
a.



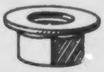
b.



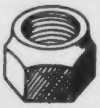
c.



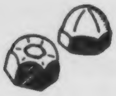
d.



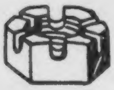
e.



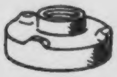
f.



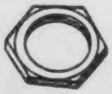
g.



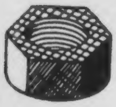
h.



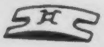
i.



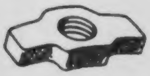
j.



k.

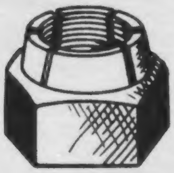


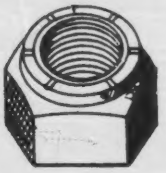
l.



m.

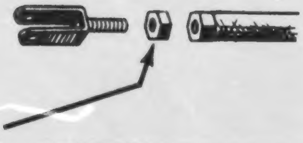
8. Identify the special purpose nuts with locking or self-locking features.

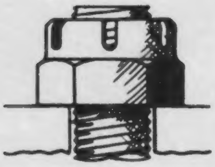




a. ____________________

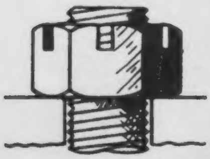
b. ____________________

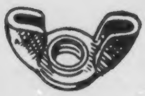




c. ____________________

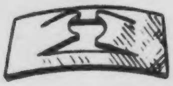
d. ____________________

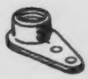




e. ____________________

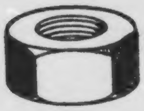
f. ____________________

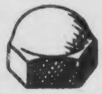




g. ____________________

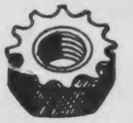
h. ____________________

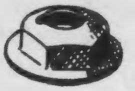




i. ____________________

j. ____________________





k. ____________________

l. ____________________

9. Select methods used to remove a seized nut by placing an "X" in the appropriate blanks.

______a. Hacksaw

______b. Chisel

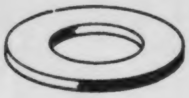
______c. Gas torch

______d. Hot water

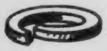
______e. Screwdriver

______f. Penetrating oil

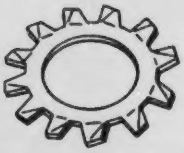
10. Identify five types of washers.



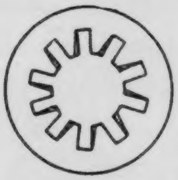
a. ______________________



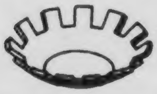
b. ______________________



c. ______________________



d. ______________________



e. ______________________

11. Select tools used to restore bolt threads by placing an "X" in the appropriate blanks.

______a. Rethreading tap

______b. Rethreading die

______c. Rethreading tool

______d. Die stock

12. Select a tool used to restore internal threads by placing an "X" in the appropriate blank.

______a. Threading die

______b. Chisel

______c. Hand tap

13. List four devices for locking nuts or bolts.

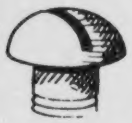
a. ____

b. ____

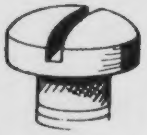
c. ____

d. ____

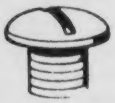
14. Identify the types of machine screw head designs.



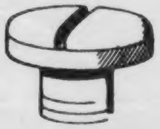
a. ____________________



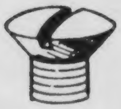
b. ____________________



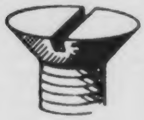
c. ____________________



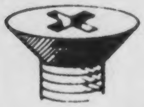
d. ____________________



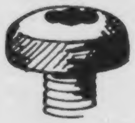
e. ____________________



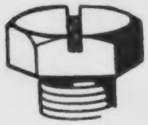
f. ____________________



g. ____________________

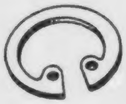


h. ____________________

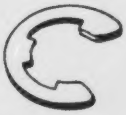


i. ____________________

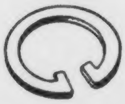
15. Identify four types of snap rings.



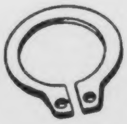
a. ____________________



b. ____________________



c. ____________________



d. ____________________

FASTENERS
UNIT V

ANSWERS TO TEST

1. a. 6
   b. 3
   c. 5
   d. 4
   e. 1
   f. 2
   g. 7

2. a, c, d, f

3. a. Hex head bolt
   b. Wing nut
   c. Stud
   d. Woodruff key
   e. Cap screw
   f. Socket head bolt
   g. Tapping screw
   h. Tooth lock washer
   i. Rivet
   j. Bolt and nut
   k. Cotter pin
   l. Square key
   m. Flat washer
   n. Plow bolt
   o. Carriage bolt
   p. Castle nut
   q. Lock washer
   r. Adhesive
   s. Lock pin
   t. Snap ring
   u. Machine screw
   v. Set screw
   w. Spring lock pin
   x. Locking nut
   y. Clevis pin

4. a. Hex head bolt
   b. Hex socket head bolt
   c. Plow bolt
   d. Square head cap screw
   e. 12-point head bolt
   f. Askew head bolt
   g. Carriage bolt
   h. Hex flange screw

5. c. Number of threads per inch is determined by measuring with a rule or a thread gauge

6. a

7. a. Castle
   b. Spring
   c. Wing
   d. Hex
   e. Flanged
   f. Lock
   g. Acorn
   h. Slotted
   i. Weld
   j. Panel
   k. Serrated
   l. Single thread
   m. Specialty

8. a. Prevailing torque lock nut
   b. Plastic insert lock nut
   c. Jam nut
   d. Castle nut
   e. Slotted nut
   f. Wing nut
   g. Speed nut
   h. Anchor nut
   i. Chamfered nut
   j. Cap nut
   k. Flange-lock nut
   l. Pal nut

9. a, b, c, f

10. a. Flat washer
    b. Lock washer
    c. External toothed lock washer
    d. Internal toothed lock washer
    e. Countersunk external toothed washer

11. b, c

12. c

13. a. Cotter pins
    b. Lock wire
    c. Flat metal locks
    d. Lock ears

14. a. Round
    b. Fillister
    c. Truss
    d. Pan
    e. Oval
    f. Flat
    g. Cross recessed or phillips
    h. Clutch
    i. Hex slotted

15. a. Internal hole
    b. External "E"
    c. Internal prong
    d. External hole

ENGINE OPERATING PRINCIPLES
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify basic parts of a diesel engine and match these parts to their functions. The student should also be able to discuss the operation of the diesel engine, distinguish between the differences in the diesel engine and the gasoline engine, and explain the basic difference between a four stroke cycle and a two stroke cycle engine. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with engine operating principles with the correct definitions.
2. Identify basic parts of a diesel engine.
3. Match basic diesel engine parts with their functions.
4. Arrange in order the sequence of the operation of the diesel engine.
5. Complete a list of what happens during each stroke of a four stroke cycle engine.
6. Differentiate between two stroke and four stroke cycle engines.
7. Differentiate between the characteristics of two stroke and four stroke cycle engines.
8. Distinguish between the differences in diesel engines and gasoline engines.
9. Calculate compression ratio.
10. Calculate cubic inch displacement.

ENGINE OPERATING PRINCIPLES
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Have students collect information on different engine types.

VII. Have students make charts on different piston designs.

VIII. Have students make a list of different parts suppliers in their area.

IX. Have students measure bore and stroke and compute displacement if an engine, with head removed, is available.

X. Show film on differences between bore and stroke.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1–Cylinder Terms
2. TM 2–Compression Ratio
3. TM 3–Piston Crown Designs
4. TM 4–Piston Stroke
5. TM 5–Basic Parts of a Diesel Engine
6. TM 6–Internal Engine Parts

7. TM 7--Diesel Engine Combustion

8. TM 8--Four Stroke Cycle Operation

9. TM 9--Two Stroke Cycle Operation

D. Assignment sheets

1. Assignment Sheet #1--Calculate Compression Ratio

2. Assignment Sheet #2--Calculate Cubic Inch Displacement

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1972.

B. *Fundamentals of Service: Engines.* 5th ed. Moline, Illinois: Deere and Company, 1980.

C. *Detroit Diesel Allison, Service Manual.* Detroit, Michigan: General Motors Corp., 1973.

D. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc. 1982.

ENGINE OPERATING PRINCIPLES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Volume--Total space between the piston at its lowest position in the cylinder and the bottom of the cylinder head (Transparency 1)

B. Clearance volume--Total space between the piston at its highest position in the cylinder and the cylinder head (Transparency 1)

C. Compression--The reduction in volume of gases trapped in the cylinder by the upward motion of the piston

D. Compression ratio--Ratio of whole cylinder volume to least cylinder volume (Transparency 2)

Example: If cylinder volume is 90 cubic inches and clearance volume is 5 cubic inches, then the compression ratio is 90÷5 = 18 or 18:1 ratio

E. Compression ignition--Ignition of the fuel by the heat from compression

F. Temperature--Measure of heat intensity

G. Combustion--Action or operation of burning

H. Pre-combustion chamber--Cavity in the cylinder head of some diesels where some burning of fuel first takes place

I. Piston crown--Surface shape of the top of the piston (Transparency 3)

J. TDC (Top Dead Center)--Piston at highest point of travel (Transparency 4)

K. BDC (Bottom Dead Center)--Piston at lowest point of travel (Transparency 4)

L. Stroke--Distance the piston moves when traveling from TDC to BDC (Transparency 4)

M. Engine speed--Crankshaft revolutions per minute

N. Power control--Controlling the engine power by varying or governing the amount of fuel injected into the combustion chamber

O. Cycle--Series of events that repeat themselves in a regular sequence

INFORMATION SHEET

II. Basic parts of a diesel engine (Transparencies 5 and 6)

   A. Cylinder block

   B. Cylinders

   C. Pistons

   D. Connecting rod

   E. Crankshaft

   F. Crankshaft gear

   G. Camshaft

   H. Timing gear

   I. Cam lobes

   J. Push rods

   K. Rocker arm

   L. Valves

   M. Valve lifter

   N. Cylinder head

   O. Cooling passageway

   P. Wrist pin

   Q. Flywheel

   R. Oil pump

   S. Oil pan

   T. Intake valve

   U. Exhaust valve

   V. Vibration damper

III. Basic diesel engine parts and their functions (Transparencies 5 and 6)

   A. Cylinder block--Solid casting which includes the cylinders and water jackets

   B. Cylinders--Holes in the cylinder block containing the pistons

INFORMATION SHEET

C. Pistons--Movable plugs open at one end which transfer force of explosion to the connecting rod

D. Connecting rod--Connecting link between the piston and crankshaft

E. Crankshaft--Main shaft of an engine which, turned by the connecting rods, changes the reciprocating motion of the piston to the rotary motion in the power train

(NOTE: Portions are offset to form throws to which the connecting rods are attached.)

F. Crankshaft gear--Drives the camshaft or idler gear

G. Camshaft--Shaft with cam lobes used to operate the valves

H. Timing gear--Gear by which the camshaft is driven by the crankshaft

I. Cam lobes--Eccentrics on the camshaft that operate the valves

J. Push rods--Rod links that transfer motion from the lifter to the rocker arm

K. Rocker arm--Transfers motion from push rod to valve to open the valve

L. Valve lifter--Rides on the camshaft so that the cam lobe raises it to operate the valve

(NOTE: The valve lifter is also called the cam follower.)

M. Valves--Open and close the cylinder to allow air to enter or gases to leave the cylinder

N. Cylinder head--Metal section bolted to the block to close one end of the cylinder, which usually contains the valves

O. Cooling passageway--Hollow space in block through which coolant circulates

P. Wrist pin--Serves as floating connecting piece for piston and connecting rod

Q. Oil pump--Provides pressure that circulates oil to rotating or reciprocating engine parts to minimize friction

R. Oil pan--Reservoir for engine oil

S. Intake valve--Permits air to enter the cylinder

INFORMATION SHEET

T. Exhaust valve--Opens and allows exhaust gases to be forced from engine cylinder

U. Flywheel--Attaches to the end of the crankshaft and provides inertia to carry the crankshaft around from one firing impulse to the other

IV. Operation of the diesel engine (Transparency 7)

A. Piston moves up on compression stroke

1. Air is trapped in the cylinder causing pressure to rise

2. Pressure rise causes high temperature

B. Piston reaches top dead center

1. Fuel is injected into the cylinder

2. Hot compressed air ignites the fuel

3. Combustion occurs

C. Combustion creates energy to force the piston down on the power stroke

(NOTE: Power is controlled by amount of fuel injected into the cylinder.)

V. Strokes in a four stroke cycle engine (Transparency 8)

A. First stroke--Intake

1. Piston moves down

2. Exhaust valve closed

3. Intake valve open

B. Second stroke--Compression

1. Piston moves up

2. Intake and exhaust valve closed

C. Third stroke--Power (ignition)

1. Piston going down

2. Intake and exhaust valve closed

INFORMATION SHEET

D. Fourth stroke--Exhaust

1. Piston moves up
2. Intake valve closed
3. Exhaust valve open

VI. Difference between two stroke and four stroke engines

A. Four stroke cycle--Fires every other time piston reaches top dead center (Transparency 8)

(NOTE: Crankshaft makes two revolutions and piston makes four strokes.)

B. Two stroke cycle--Fires each time piston reaches top dead center (Transparency 9)

(NOTE: Crankshaft makes one revolution and piston makes two strokes but completes all four events in the cycle. Cylinder has been charged by a blower forcing air through ports near bottom of cylinder.)

VII. Characteristics of two-cycle and four-cycle engines

A. Two-cycle

1. Produces a power stroke for each revolution of the crankshaft
2. Theoretically produces twice the power for the same size engine
3. Smoother running as power strokes occur at shorter intervals

B. Four-cycle

1. Heat problem is less due to each cylinder firing half as often
2. Does not use engine power to drive a blower to force air charge into the cylinder under pressure
3. Burned gases are completely cleared from the cylinder, resulting in more power per power stroke
4. Exhaust valves or ports open later creating some gain in effective power

INFORMATION SHEET

VIII. Diesel and gasoline engine differences

- A. Fuel ignition
    1. Diesel--Ignition by compression
    2. Gasoline--Ignition by electrical spark
- B. Intake air
    1. Diesel--Takes fresh air directly to combustion chamber
    2. Gasoline--Takes fresh air and fuel through carburetor, then to combustion chamber
- C. Compression
    1. Diesel--High compression ratio (16-22:1)
    2. Gasoline--Low compression ratio (7-11:1)
- D. Fuel
    1. Diesel--Burns low grade fuel oil
    2. Gasoline--Burns gasoline
- E. Fuel delivery system
    1. Diesel--Fuel injected directly into combustion chamber
    2. Gasoline--Fuel and air mixture drawn through carburetor and intake manifold into combustion chamber
- F. Construction
    1. Diesel--Heavier construction

       (NOTE: Heavy construction is required to handle the high pressure and temperature generated in a diesel engine.)
    2. Gasoline--Lighter construction

INFORMATION SHEET

IX. How to calculate compression ratio

A. Figure clearance volume

1. Fill head or piston with liquid (diesel or gasoline) from a graduated cylinder

2. Figure amount of liquid used by subtracting amount left in cylinder from total amount; this number is clearance volume in cubic centimeters

3. Convert cubic centimeters into cubic inches using the following formula:

   1 $\text{centimeter}^3 = .061\ \text{inches}^3$

   Example: If the clearance volume is 80 cubic centimeters, then the clearance volume in inches is 80 x .061 = 4.88 cubic inches

B. Figure total volume by using the following formula:

$$\frac{D^2 \text{ (Diameter of Bore)} \times S \text{ (Stroke)} \times \pi \text{ (3.14)}}{4} = \text{total volume}$$

Example: If the diameter is 6" and the stroke is 6", then the total volume is 6 (6 x 6 x 3.14) ÷ 4 = 169.56 cubic inches

C. Figure compression ratio by dividing total volume by clearance volume

Example: If the total volume is 90 cubic inches and the clearance volume is 5 cubic inches, then the compression ratio is 90 divided by 5 equals 18 or 18:1 ratio

X. How to calculate cubic inch displacement

(NOTE: Metric measurement for displacement is in cubic centimeters or liters.)

A. Measure diameter of bore

B. Measure length of stroke

C. Calculate cubic inch displacement using either of the following formulas:

1. $$\frac{D^2 \times S \times \pi \times \text{Number of cylinders}}{4} = \text{C.I.D.}$$

   Example: If the diameter is 4", the length of stroke is 4", and the number of cylinders is 8, then the cubic inch displacement is $(4^2 \times 4 \times 3.14 \times 8) \div 4 = 401.92$

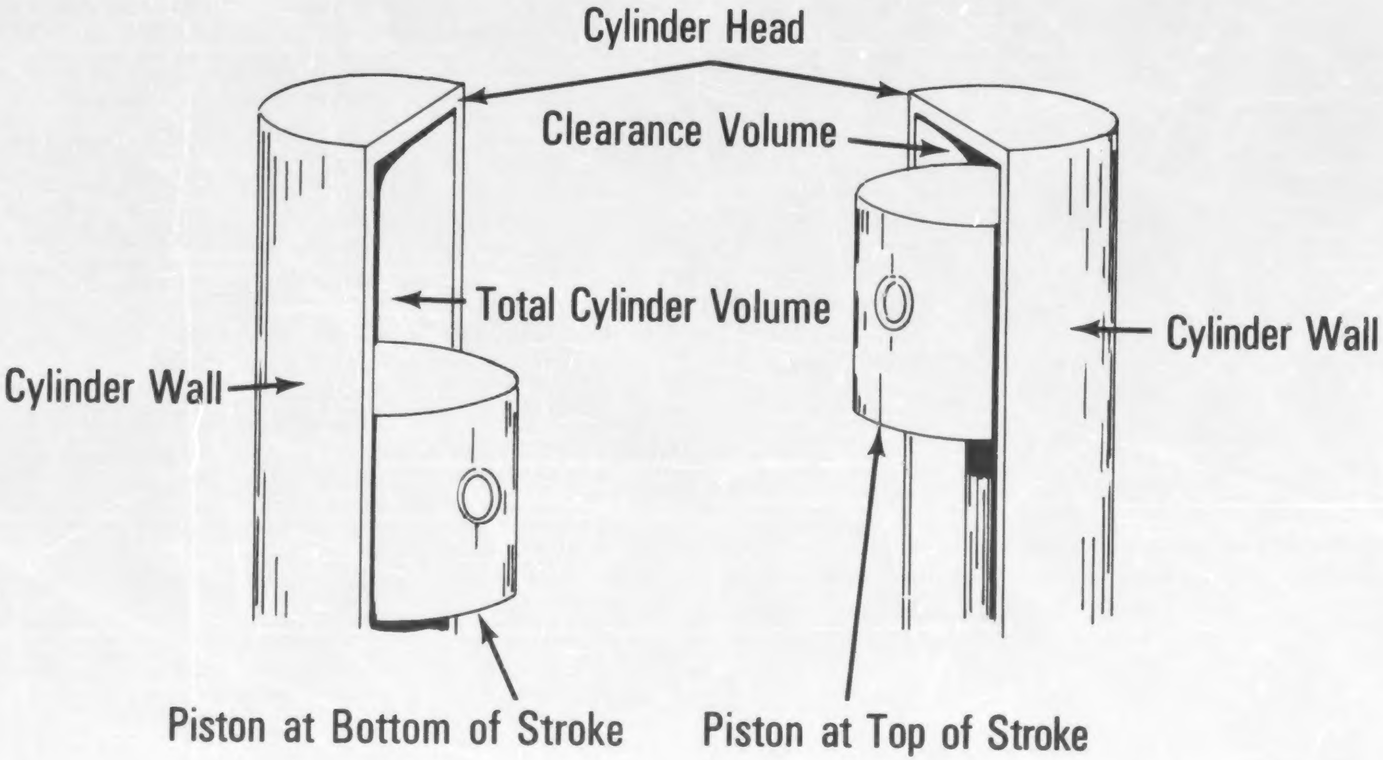
INFORMATION SHEET

2. $D^2 \times S \times .7854 \times$ Number of cylinders = C.I.D.

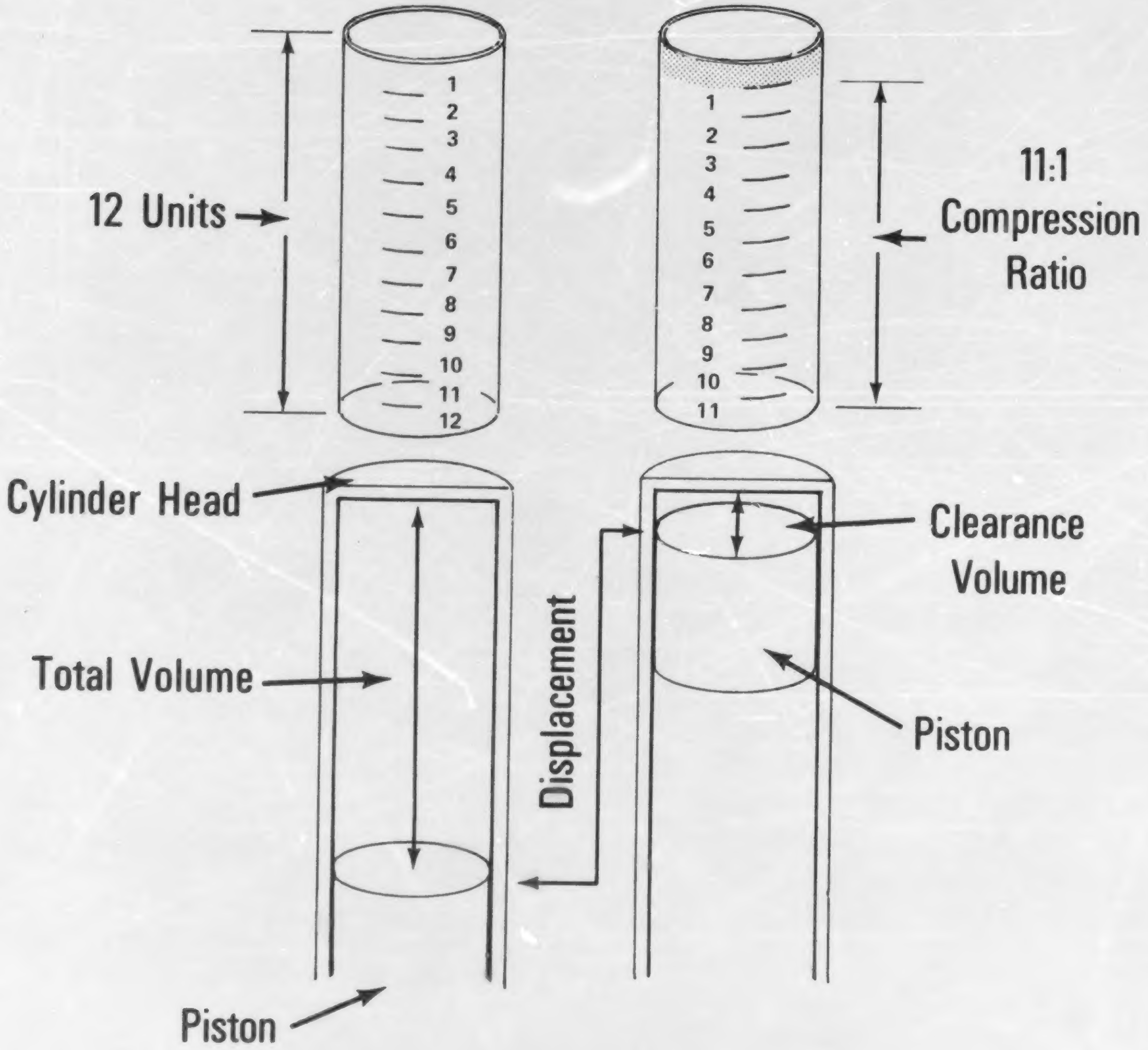
   (NOTE: This formula is more accurate.)

   Example: If the diameter is 4", the length of stroke is 4", and the number of cylinders is 8, then the cubic inch displacement is $4^2 \times 4 \times .7854 \times 8 = 402.1248$

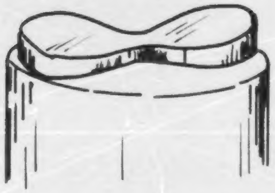
Cylinder Terms


Cylinder Head
Clearance Volume
Total Cylinder Volume
Cylinder Wall
Cylinder Wall
Piston at Bottom of Stroke
Piston at Top of Stroke

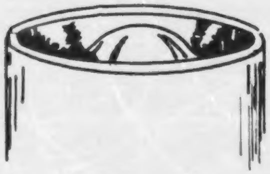
Compression Ratio


12 Units
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
11:1
Compression
Ratio
Cylinder Head
Total Volume
Displacement
Clearance
Volume
Piston
Piston

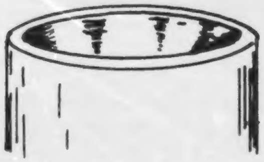
Piston Crown Designs



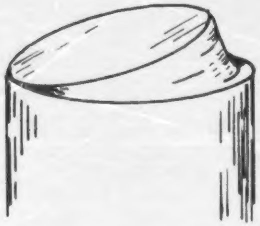
International Harvester
Super M 400



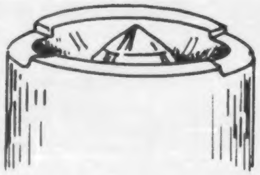
Cummins V-8



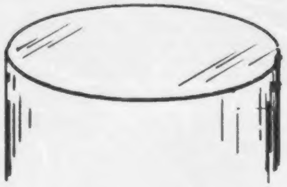
Hercules G-3400



High Compression

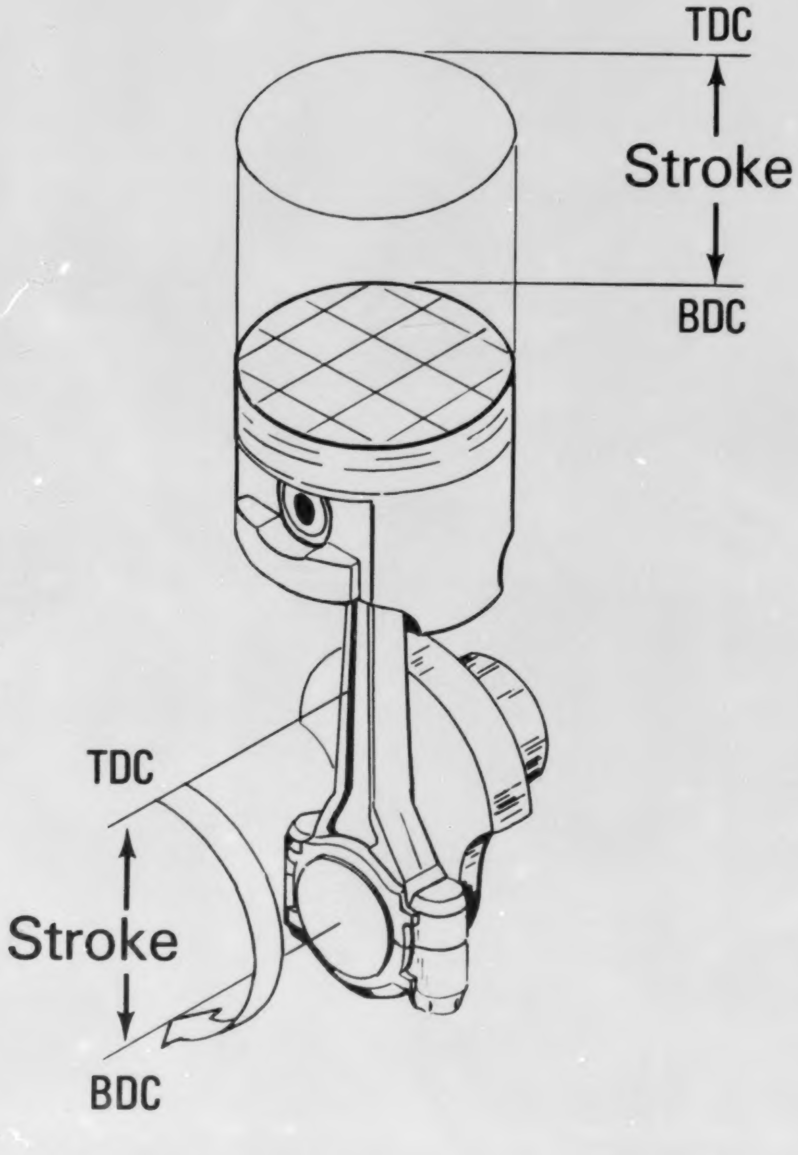


NH Cummins

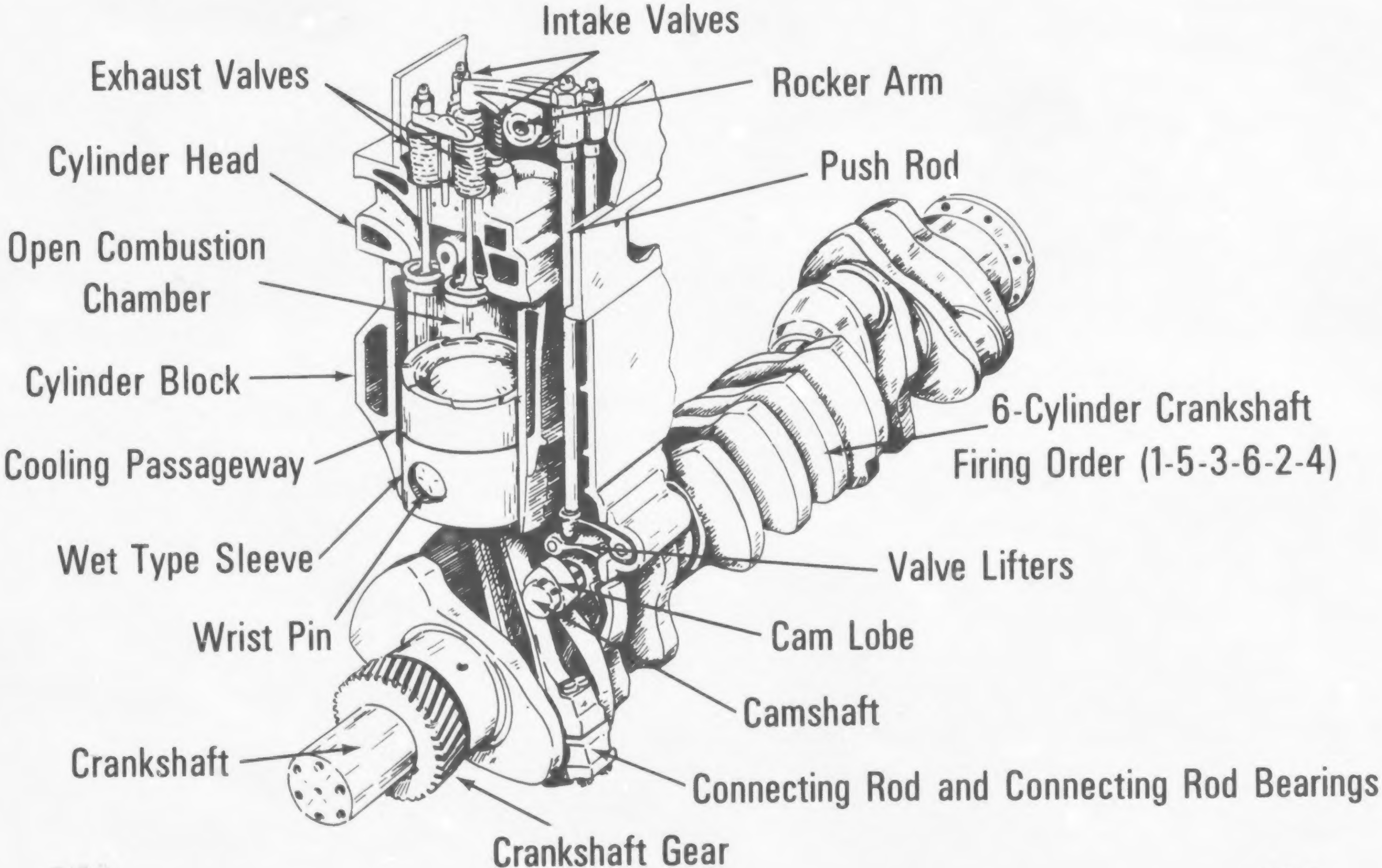


Flat Top

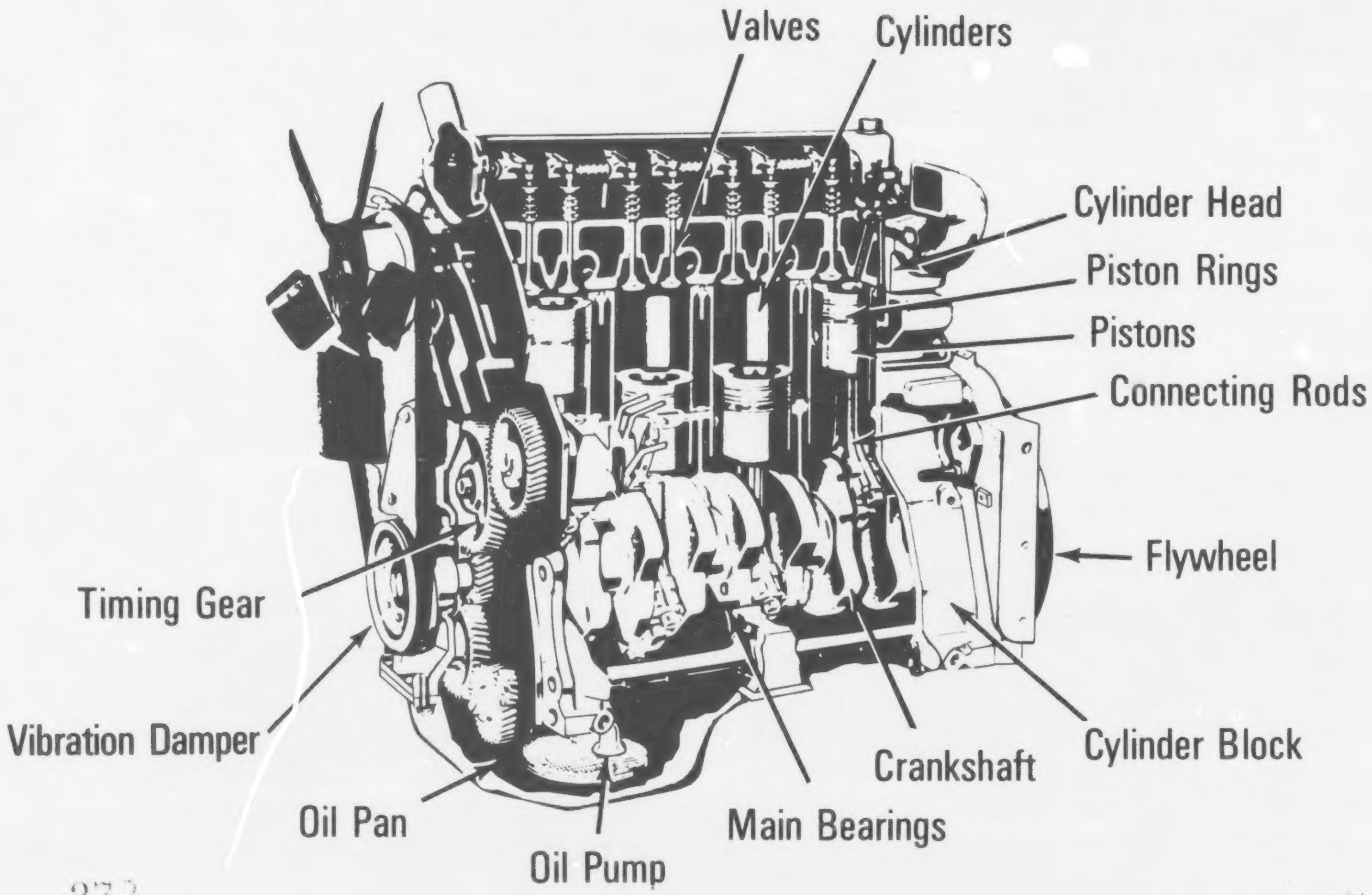
Piston Stroke


TDC
Stroke
BDC
TDC
Stroke
BDC

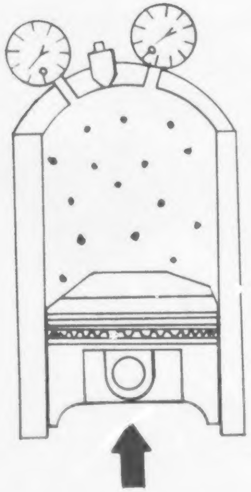
Basic Parts of a Diesel Engine


Intake Valves
Exhaust Valves
Rocker Arm
Cylinder Head
Push Rod
Open Combustion Chamber
Cylinder Block
6-Cylinder Crankshaft Firing Order (1-5-3-6-2-4)
Cooling Passageway
Wet Type Sleeve
Valve Lifters
Wrist Pin
Cam Lobe
Camshaft
Crankshaft
Connecting Rod and Connecting Rod Bearings
Crankshaft Gear

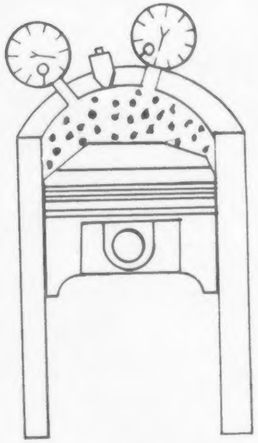
Internal Engine Parts


Valves
Cylinders
Cylinder Head
Piston Rings
Pistons
Connecting Rods
Flywheel
Timing Gear
Vibration Damper
Oil Pan
Oil Pump
Main Bearings
Crankshaft
Cylinder Block

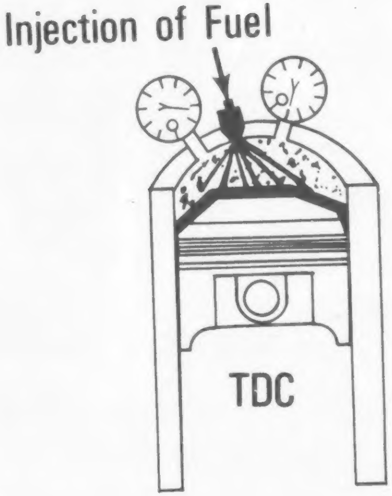
Diesel Engine Combustion



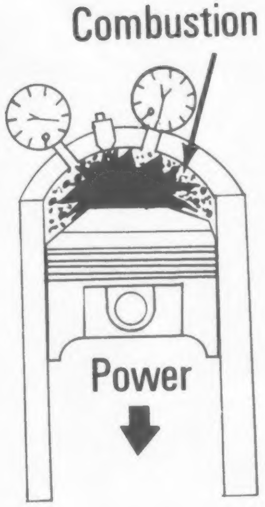
Piston moves up on compression stroke



Air is trapped in the cylinder causing pressure to rise

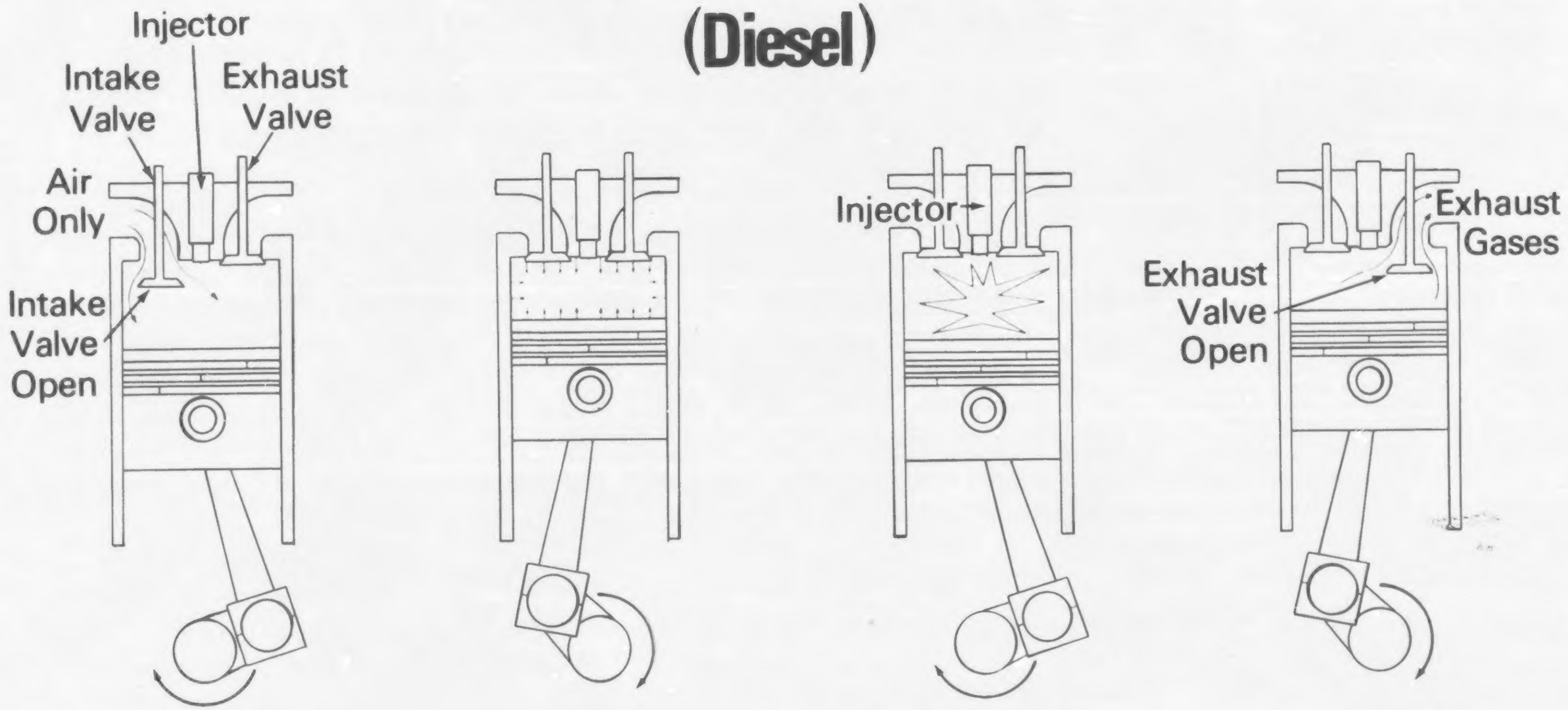

Injection of Fuel
TDC

Piston reaches TDC and fuel is injected into the cylinder


Combustion
Power

Hot compressed air ignites the fuel, combustion occurs, and this creates energy to force the piston down on the power stroke

Four Stroke Cycle Operation
(Diesel)


Injector
Intake Valve
Exhaust Valve
Air Only
Intake Valve Open
Injector
Exhaust Valve Open
Exhaust Gases

Intake

Air is drawn into cylinder through open intake valve by downward-stroke of piston.

Compression

Air is compressed by upward-stroke of piston. Both intake and exhaust valves are closed.

Power

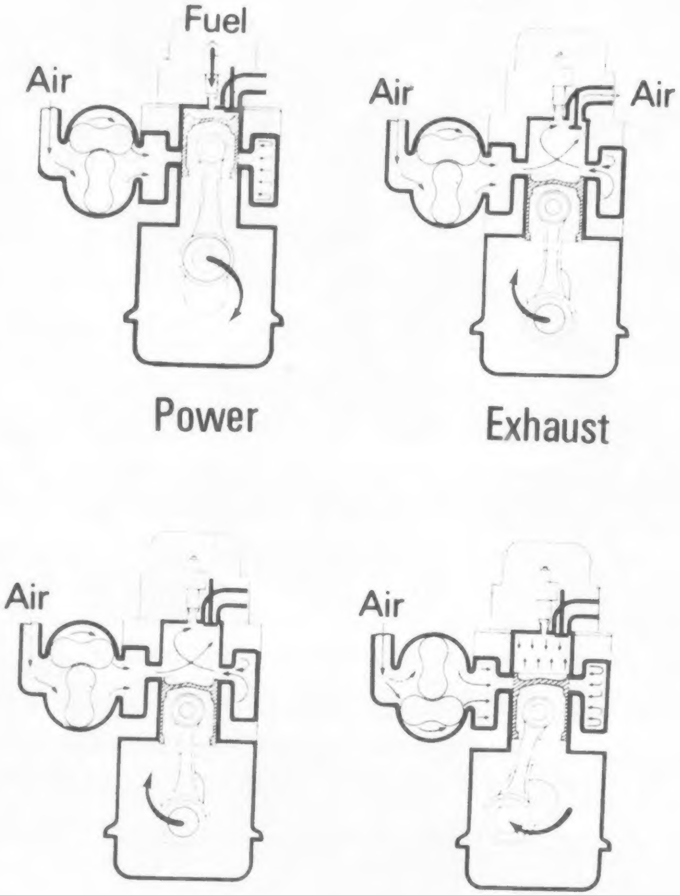
Fuel is injected. Compressed air ignites the fuel and expanding gases force piston to bottom of cylinder. Valves remain closed.

Exhaust

Piston on upward-stroke forces burned gases from cylinder through open exhaust valve.

Reprinted from *Diesel Mechanics* by permission of McGraw-Hill, Inc., Copyright 1977.

Two Stroke Cycle Operation

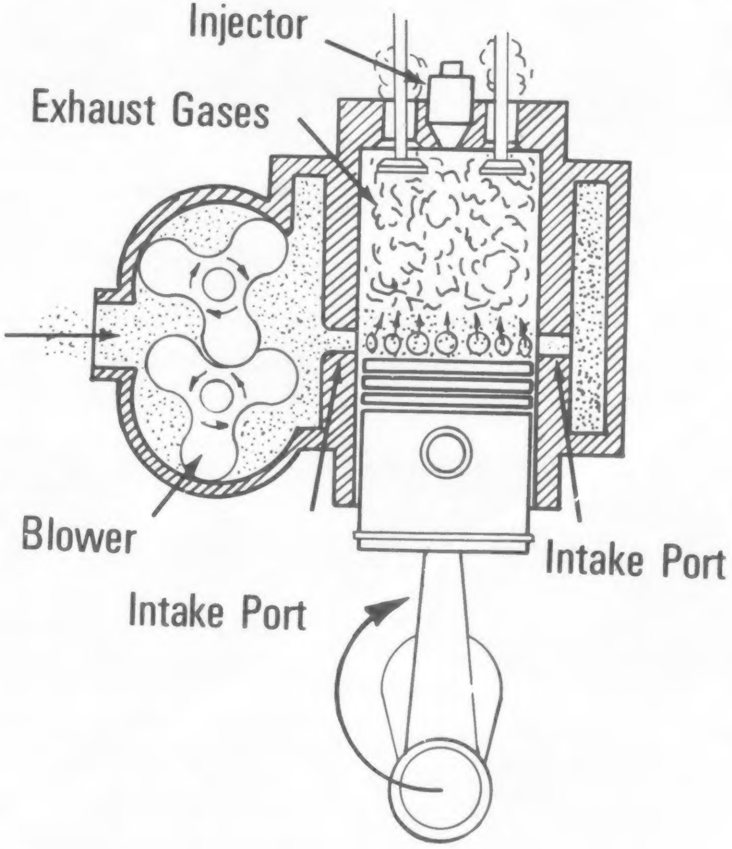

Fuel
Air
Air
Air
Air
Air

Power

Exhaust

Intake

Compression


Injector
Exhaust Gases
Blower
Intake Port
Intake Port

Reprinted from *Diesel Mechanics* by permission of McGraw-Hill, Inc., Copyright 1977.

ENGINE OPERATING PRINCIPLES
UNIT I

ASSIGNMENT SHEET #1--CALCULATE COMPRESSION RATIO

Directions: Calculate the compression ratios for the following engines using the information given.

a. Clearance volume 3 cubic inches
   Total volume 85 cubic inches

   Compression ratio ____________________

b. Clearance volume 5 cubic inches
   Total volume 100 cubic inches

   Compression ratio ____________________

c. Clearance volume 7 cubic inches
   Total volume 89 cubic inches

   Compression ratio ____________________

d. Clearance volume 23 cubic inches
   Total volume 300 cubic inches

   Compression ratio ____________________

e. Clearance volume 50 cubic inches
   Total volume 1000 cubic inches

   Compression ratio ____________________

ENGINE OPERATING PRINCIPLES
UNIT I

ASSIGNMENT SHEET #2--CALCULATE CUBIC INCH DISPLACEMENT

Directions: Calculate cubic inch displacement using the information given.

a. Diameter of bore--5 1/8
Length of stroke--6
Number of cylinders--6
Cubic inch displacement = ______________________________

b. Diameter of bore--4 7/16
Length of stroke--5
Number of cylinders--6
Cubic inch displacement = ______________________________

c. Diameter of bore--5 1/2
Length of stroke--6
Number of cylinders--6
Cubic inch displacement = ______________________________

d. Diameter of bore--5.4
Length of stroke--6.5
Number of cylinders--8
Cubic inch displacement = ______________________________

ENGINE OPERATING PRINCIPLES
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. 28.333:1

b. 20:1

c. 12.714:1

d. 13.044:1

e. 20:1

Assignment Sheet #2

a. 742.64478 or 742.26655

b. 463.9689 or 463.7326

c. 855.3006 or 854.865

d. 1190.3112 or 1190.9177

ENGINE OPERATING PRINCIPLES
UNIT I

NAME____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Total space between the piston at its lowest position in the cylinder and the bottom of the cylinder head

_____b. Total space between the piston at its highest position in the cylinder and the cylinder head

_____c. The reduction in volume of gases trapped in the cylinder by the upward motion of the piston

_____d. Ratio of whole cylinder volume to least cylinder volume

_____e. Ignition of the fuel by the heat from compression

_____f. Measure of heat intensity

_____g. Action or operation of burning

_____h. Cavity in the cylinder head of some diesels where some burning of fuel first takes place

_____i. Piston at highest point of travel

_____j. Piston at lowest point of travel

_____k. Distance the piston moves when traveling from TDC to BDC

_____l. Crankshaft revolutions per minute

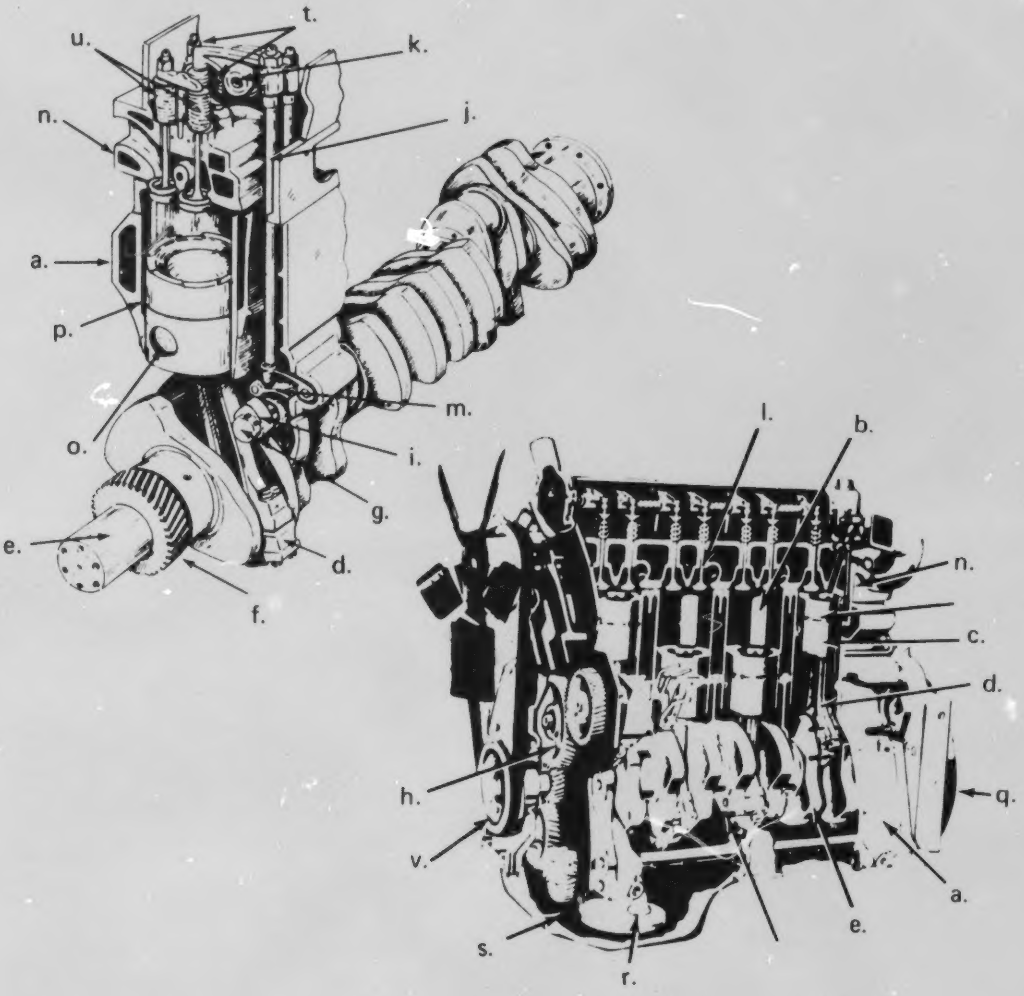
_____m. Controlling the engine power by varying or governing the amount of fuel injected into the combustion chamber

_____n. Surface shape of the top of the piston

_____o. Series of events that repeat themselves in a regular sequence

1. Piston crown
2. Power control
3. Engine speed
4. Stroke
5. BDC (Bottom Dead Center)
6. TDC (Top Dead Center)
7. Combustion
8. Pre-combustion chamber
9. Compression
10. Temperature
11. Compression ignition
12. Compression ratio
13. Volume
14. Cycle
15. Clearance volume

2. Identify fifteen basic parts of a diesel engine.


t.
u.
k.
n.
j.
a.
p.
m.
o.
i.
g.
e.
d.
f.
l.
b.
n.
c.
d.
h.
q.
v.
a.
e.
s.
r.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

k. ______________________

l. ______________________

m. ______________________

n. ______________________

o. ______________________

p. ______________________

q. ______________________

r. ______________________

s. ______________________

t. ______________________

u. ______________________

v. ______________________

3. Match the basic parts on the right with their correct functions. (The answers for "a" through "l" are on this page.)

_____a. Solid casting which includes the cylinders and water jackets

_____b. Holes in the cylinder block containing the pistons

_____c. Movable plugs open at one end which transfer force of explosion to the connecting rod

_____d. Connecting link between the piston and crankshaft

_____e. Main shaft of an engine which, turned by the connecting rods, changes the reciprocating motion of the piston to the rotary motion in the power train

_____f. Drives the camshaft or idler gear

_____g. Shaft with cam lobes used to operate the valves

_____h. Gear by which the camshaft is driven by the crankshaft

_____i. Eccentrics on the camshaft that operate the valves

_____j. Rod links that transfer motion from the lifter to the rocker arm

_____k. Transfers motion from push rod to valve to open the valve

_____l. Rides on the camshaft so that the cam lobe raises it to operate the valve

1. Valve lifter
2. Connecting rod
3. Crankshaft
4. Push rods
5. Rocker arm
6. Timing gear
7. Cylinders
8. Cylinder block
9. Cam lobes
10. Pistons
11. Crankshaft gear
12. Camshaft

______m. Opens and allows exhaust gases to be forced from engine cylinder

______n. Metal section bolted to the block to close one end of the cylinder, which usually contains the valves

______o. Provides pressure that circulates oil to rotating or reciprocating engine parts to minimize friction

______p. Serves as floating connecting piece for piston and connecting rod

______q. Hollow space in block through which coolant circulates

______r. Reservoir for engine oil

______s. Permits air to enter the cylinder

______t. Open and close the cylinder to allow air to enter or gases to leave the cylinder

______u. Attaches to the end of the crankshaft and provides inertia to carry the crankshaft around from one firing impulse to the other

13. Valves
14. Oil pan
15. Flywheel
16. Oil pump
17. Intake valve
18. Cylinder head
19. Exhaust valve
20. Cooling passageway
21. Wrist pin

4. Arrange in order the sequence of the operation of the diesel engine by placing the correct sequence number in the appropriate blank.

______a. Piston reaches top dead center

   1. Fuel is injected into the cylinder
   2. Hot compressed air ignites the fuel
   3. Combustion occurs

______b. Combustion creates energy to force the piston down on the power stroke

______c. Piston moves up on compression stroke

   1. Air is trapped in the cylinder causing pressure to rise
   2. Pressure rise causes high temperature

5. Complete the following list of what happens during each stroke of a four stroke cycle engine.

   a. First stroke--Intake

      1. Piston moves down
      2. Exhaust valve closed
      3. ____

b. Second stroke--Compression

1. Intake and exhaust valve closed
2. ____________________

c. Third stroke--Power (ignition)

1. ____________________
2. Intake and exhaust valve closed

d. Fourth stroke--Exhaust

1. Piston moves up
2. ____________________
3. Exhaust valve open

6. Differentiate between two stroke and four stroke engines by placing an "X" next to the description of a four stroke cycle.

______a. Fires every other time piston reaches top dead center

______b. Fires each time piston reaches top dead center

7. Differentiate between the characteristics of two-cycle and four-cycle engines by placing an "X" next to the characteristics of a two-cycle engine.

______a. Does not use engine power to drive a blower to force air charge into the cylinder under pressure

______b. Produces a power stroke for each revolution of the crankshaft

______c. Heat problem is less due to each cylinder firing half as often

______d. Exhaust valves or ports open later creating some gain in effective power

______e. Theoretically produces twice the power for the same size engine

______f. Smoother running as power strokes occur at shorter intervals

______g. Burned gases are completely cleared from the cylinder, resulting in more power per power stroke

8. Distinguish between the differences in diesel engines and gasoline engines by placing an "X" next to the descriptions of diesel engines.

______a. Ignition by compression

______b. Burns gasoline

______c. Lighter construction

______d. High compression ratio

______e. Heavier construction

______f. Takes fresh air directly to combustion chamber ______g. Ignition by electrical spark

______h. Low compression ratio

______i. Burns low grade fuel oil

______j. Fuel and air mixture drawn through carburetor and intake manifold into combustion chamber

______k. Takes fresh air and fuel through carburetor then to combustion chamber

______l. Fuel injected directly into combustion chamber

9. Calculate compression ratio using the following information:

Total volume = 150
Clearance volume = 7
Compression ratio = ______________________________

10. Calculate cubic inch displacement using the following information:

Bore = 5
Stroke = 6
Number of cylinders = 6
Cubic inch displacement = ____________________________

ENGINE OPERATING PRINCIPLES
UNIT I

ANSWERS TO TEST

1. a. 13
   b. 15
   c. 9
   d. 12
   e. 11
   f. 10
   g. 7
   h. 8
   i. 6
   j. 5
   k. 4
   l. 3
   m. 2
   n. 1
   o. 14

2. Any fifteen of the following:

   a. Cylinder block
   b. Cylinders
   c. Pistons
   d. Connecting rod
   e. Crankshaft
   f. Crankshaft gear
   g. Camshaft
   h. Timing gear
   i. Cam lobes
   j. Push rods
   k. Rocker arm
   l. Valve
   m. Valve lifter
   n. Cylinder head
   o. Wrist pin
   p. Cooling passageway
   q. Flywheel
   r. Oil pump
   s. Oil pan
   t. Intake valve
   u. Exhaust valve
   v. Vibration damper

3. a. 8
   b. 7
   c. 10
   d. 2
   e. 3
   f. 11
   g. 12
   h. 6
   i. 9
   j. 4
   k. 5
   l. 1
   m. 19
   n. 18
   o. 16
   p. 21
   q. 20
   r. 14
   s. 17
   t. 13
   u. 15

4. a. 2
   b. 3
   c. 1

5. a. Intake valve open
   b. Piston moves up
   c. Piston going down
   d. Intake valve closed

6. a

7. b, e, f

8. a, d, e, f, i, l

9. 21.428571

10. Either of the following:

    a. 706.5
    b. 706.86

DIESEL FUELS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the characteristics of diesel fuels and arrange in order the operating principles that describe the diesel fuel combustion cycle. The student should also be able to list two important considerations when storing diesel fuel and select the methods used to protect fuel quality. This knowledge will be evidenced by correctly performing the procedure outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with diesel fuels with the correct definitions.
2. Arrange in order the operating principles that describe the diesel fuel combustion cycle.
3. Match the properties of diesel fuel with the correct definitions.
4. List crude oil by-products.
5. Complete a list of characteristics of diesel fuels.
6. Name two grades of commercial diesel fuel meeting ASTM standards.
7. Distinguish between the cause of diesel ignition knock and the cause of gasoline ignition knock.
8. List three most likely causes of black smoke from a diesel exhaust.
9. List two most likely causes of white smoke from a diesel exhaust.
10. List two important considerations when storing diesel fuel.
11. Select the methods and rules used to protect fuel quality.
12. Select the number of feet required for safe spacing of diesel fuel storage tanks.
13. Demonstrate the ability to measure specific gravity of diesel fuel.

DIESEL FUELS
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss procedures outlined in the job sheet.

VII. Take students on tour of fuel storage facilities.

VIII. Take students on field trip to a refinery.

IX. Have students complete a list of different refineries in their area.

X. Show students the effects of water in fuel.

XI. Invite representative from an oil company to speak on fuels.

XII. Show film on fuel refining.

XIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Diesel Combustion Cycle

    2. TM 2--ASTM Limiting Requirements for Diesel Fuels

    3. TM 3--Safe Spacing of Storage Tanks

  D. Job Sheet #1--Measure Specific Gravity of Diesel Fuel

  E. Test

  F. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. *Fundamentals of Service: Fuels, Lubricants, and Coolants.* 4th ed. Moline, Illinois: Deere and Company, 1980.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

DIESEL FUELS
UNIT II

INFORMATION SHEET

I. Terms and definitions

  A. Crude oil--Mixture of hydrocarbons in natural state

  B. Hydrocarbons--Compounds consisting of hydrogen and carbon

  C. ASTM--American Society of Testing Materials

  D. Volatility--Ability of a liquid to change into a vapor when heated

  E. No. 1-D diesel fuel--ASTM classification of volatile fuel oils from kerosene to intermediate distillates

  F. No. 2-D diesel fuel--Class of distillate gas oils of lower volatility than kerosene

II. Diesel fuel combustion cycle (Transparency 1)

  A. Air only enters cylinder

  B. Air is compressed

  C. Fuel is sprayed into combustion chamber

  D. Fuel-air ignites from heat of compression

III. Properties of diesel fuel and definitions

  A. Heat value--Amount of power fuel will provide when burned

  B. Specific gravity--Ratio of density of fuel (oil) to density of water

  C. Flash point--Oil temperature at which flammable vapor driven off will ignite from an open flame

  D. Cetane number--Ease with which the fuel will ignite expressed in numbers

  (NOTE: Commercial diesel fuel cetane numbers range from 33 to 64.)

  E. Carbon residue--Matter left after evaporation and chemical decomposition

  F. Sulfur content--Causes corrosion and deposit formations in an engine

  G. Ash--Unburnable residue in the form of soluble metallic soaps and abrasive solids

INFORMATION SHEET

   H. Viscosity--Resistance of a liquid to flow

   I. Pour point--Lowest temperature at which fuel ceases to flow

IV. Crude oil by-products

(NOTE: These by-products are listed in the order they are given off.)

   A. Natural gas

   (NOTE: This natural gas is used for homes, industry, and some engines.)

   B. High octane aviation gas

   C. Automotive gasoline

   D. Finished kerosene

   E. Domestic heating oil

   F. Hydrocarbon gases

   (NOTE: These raw materials are used in the manufacture of high octane gasoline, synthetic rubber, plastics, paints and varnishes, alcohols and solvents, explosives, and many other products.)

   G. Industrial fuel oil (diesel fuel)

   H. Finished lubricating oils

   I. Wax (paraffin)

   J. Gas oil

   K. Coke

   L. Asphalt

(NOTE: As crude oil is refined, approximately 44 percent is gasoline, 36 percent is fuel oil, and the balance is kerosene, lubricants, and by-products.)

V. Characteristics of diesel fuel

   A. Permits engine start at lower air temperatures

   B. Provides faster engine warm-up

   C. Reduces the rate of formation of varnish and carbon deposits

   D. Eliminates combustion roughness or carbon knock

INFORMATION SHEET

VI. Commercial diesel fuels meeting ASTM standards (Transparency 2)

  A. No. 1-D

  B. No. 2-D

VII. Causes of ignition knock

  A. Diesel--Due to fuel igniting too slowly

  (NOTE: Diesel fuel must burn fast.)

  B. Gasoline--Due to fuel burning too fast and uneven explosions

  (NOTE: Gasoline must burn evenly.)

VIII. Causes of black smoke from a diesel exhaust

  A. Faulty fuel injection

  B. Overfueling

  C. Restricted air intake

IX. Causes of white smoke from a diesel exhaust

  A. Unburned fuel

  B. Partially burned fuel

X. Storing diesel fuel

  A. Keep fuel free of dirt and water

  B. Avoid gum deposits

XI. Methods and rules used to protect fuel quality

(NOTE: The fuel injection system on a diesel engine is fitted with parts that are held within millionths of an inch clearance. Very fine dirt particles soon ruin the parts and cause an expensive repair job. Water, even extremely small amounts, causes corrosion which ruins the highly polished surfaces of the injection system components.)

  A. Do not let water collect on top of fuel barrels or storage tank

  (NOTE: Water retained on the tank tends to rust the outside of the drum and as fuel is drawn from the tank, water may be drawn through the air vent directly into your fuel supply.)

INFORMATION SHEET

B. Do not use an open container to transfer fuel from the storage tank to the machine tank

(NOTE: This greatly increases the chance for dirt to enter the fuel tank. Equip the aboveground tank with a pump and hose or a gravity hose to transfer fuel. Be sure to cap the end of the hose nozzle while the hose is not in use.)

C. Do not store diesel fuel in a galvanized tank

(NOTE: When diesel fuel is stored in a galvanized tank, the fuel reacts with the galvanized finish, causing powdering particles to form. They soon clog the fuel filters on a diesel engine. Using a steel tank will avoid this.)

D. Do not use a tank formerly used for gasoline storage

(NOTE: Fine rust and dirt particles that settled out of gasoline and accumulated on the bottom of the tank mix readily with diesel fuel and may remain suspended in it until drawn from the tank.)

E. Do not let the suction pipe to the fuel pump extend to the bottom of the storage tank

(NOTE: This permits the pump to pick up water and sediment that has settled out of the fuel. The end of the pipe should be 3 to 4 inches from the bottom. If possible, slope the tank away from the pipe or outlet valve.)

F. Always drain the storage tank before refilling and clean the tank regularly

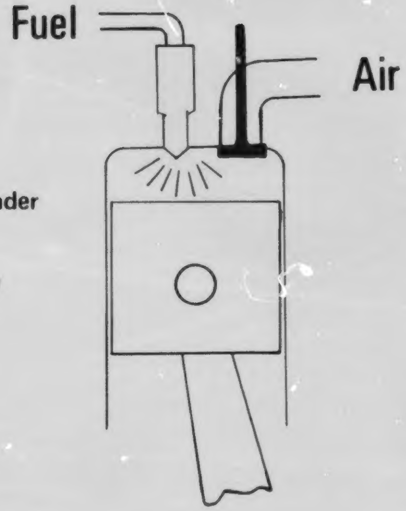
(NOTE: This will prevent the dirt and water residue from rising high enough to be drawn out with the fuel.)

XII. Safe spacing of fuel tanks (Transparency 3)

A. Forty feet from nearest building for aboveground tanks

B. One foot from nearest building for underground tanks

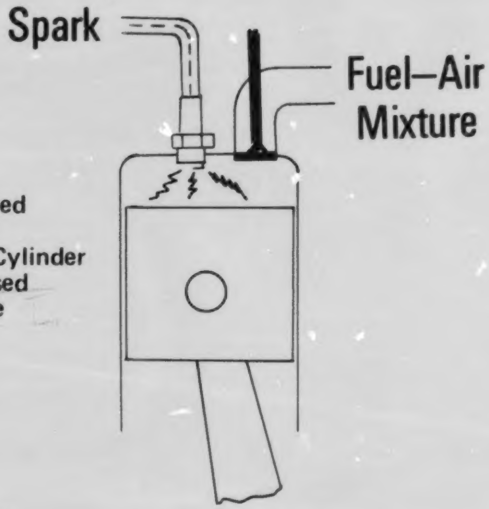
Diesel Combustion Cycle



1. Air Only Enters Cylinder
2. Air is Compressed
3. Fuel is Sprayed in
4. Fuel -Air Ignites from Heat of Compression

Average Compression Ratio: 16 to 1

Diesel



1. Fuel-Air are Mixed in Carburetor
2. Mixture Enters Cylinder and is Compressed
3. Spark Ignites the Mixture

Average Compression Ratio: 8 to 1

Gasoline

ASTM Limiting Requirements for Diesel Fuels

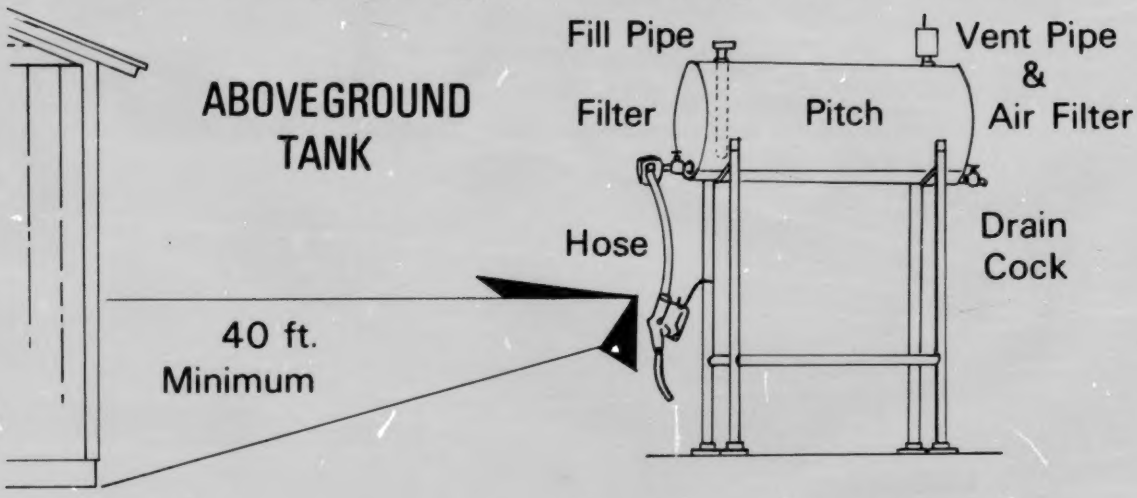
Diesel Fuel ***	Flash Point, °F.	Pour Point, °F.	Water and Sediment, % vol.	Carbon Residue on 10% Residuum, %	Ash, % wt.	90% Distillation Temperature, °F.		Viscosity at 100°F, Centistokes		Sulfur % wt.	Copper Strip Corrosion	Cetane Number
	Min.	Max.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Max.	Max.	Min.
No. 1-D	100 or legal	*	Trace	0.15	0.01	—	550	1.4	2.5	0.50	No. 3	40
No. 2-D	125 or legal	*	0.05	0.35	0.01	540**	640	2.0**	4.3	0.50	No. 3	40

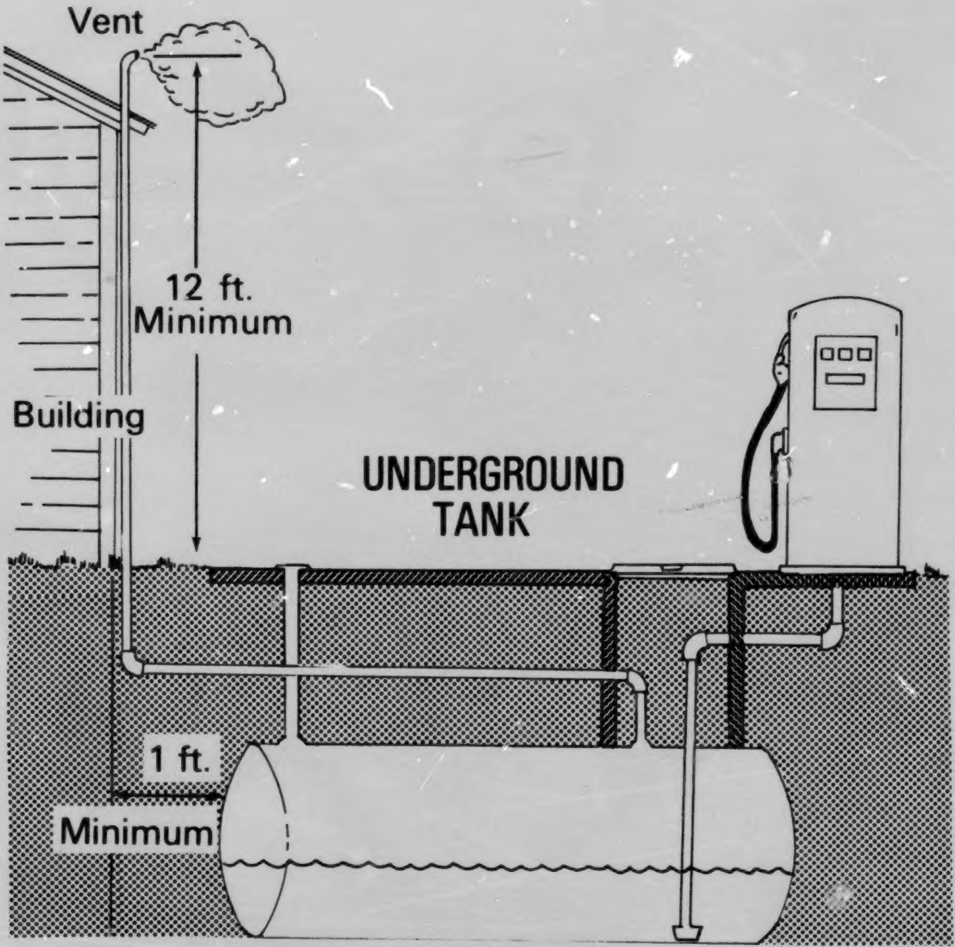
*For cold weather operation, the pour point should be specified 10°F. below the ambient temperature at which the engine is to be operated except where fuel oil heating facilities are provided.

**When pour point less than 0°F. is specified, the minimum viscosity shall be 1.8 cs and the minimum of 90% point shall be waived.

***A diesel fuel of low volatility, No. 4-D, is recommended only for low- and medium-speed engines.

Safe Spacing of Storage Tanks


ABOVEGROUND TANK
Fill Pipe
Vent Pipe & Air Filter
Filter
Pitch
Hose
Drain Cock
40 ft. Minimum


Vent
12 ft. Minimum
Building
UNDERGROUND TANK
1 ft. Minimum

DIESEL FUELS
UNIT II

JOB SHEET #1--MEASURE SPECIFIC GRAVITY OF DIESEL FUEL

I. Tools and materials

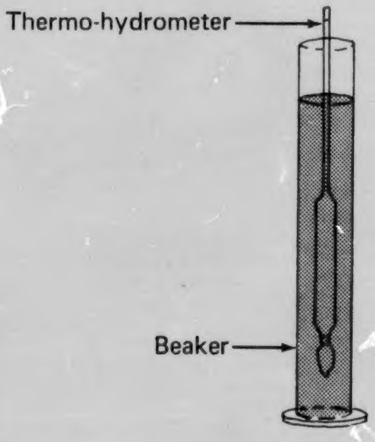
- A. Beaker
- B. Thermo-hydrometer
- C. Clean shop towels
- D. Safety glasses
- E. Diesel fuel

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Fill a 1P7438 beaker about two-thirds full of the diesel fuel to be tested
- B. Lower the thermo-hydrometer carefully into the fuel (Figure 1)

FIGURE 1

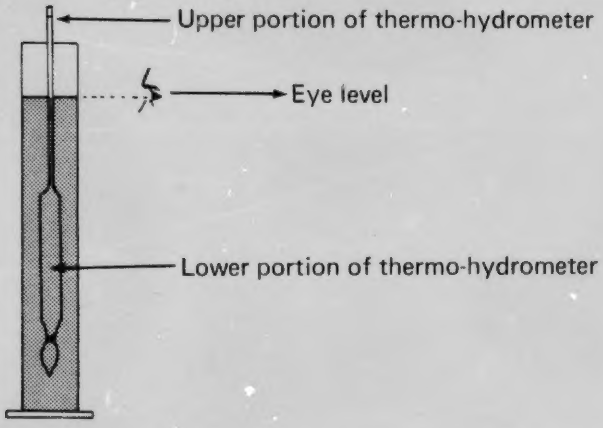


- C. Push the thermo-hydrometer to below its float level; then allow it to float freely
- D. Wait two or three minutes until the thermo-hydrometer is stationary so there are no air bubbles in the fuel, and the thermometer reading stabilizes

JOB SHEET #1

E. Read the measured API gravity directly from the thermo-hydrometer; use the scale on the narrow upper portion (Figure 2)

FIGURE 2


Upper portion of thermo-hydrometer
Eye level
Lower portion of thermo-hydrometer

F. Record the observed API gravity to the nearest full degree of API

(NOTE: If the fuel is not clear, read from above the surface and estimate as accurately as possible the point to which the fuel rises on the hydrometer scale.)

G. Record the corrected API gravity from the chart (Figure 3)

FIGURE 3

Measured Temperature °F	Measured API gravity																								
	29°	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	51°	52°	53°
	Corrected API Gravity At 60° F (15°C)																								
0°	33	34	35	36	37	38.5	39.5	41	42	43	44	45	46	47	48.5	49.5	50.5	52	53	54	55	56	57.5	58.5	60
10°	32.5	33.5	34.5	35.5	36.5	38	39	40	41	42	43	44	45	46	47.5	48.5	49.5	51	52	53	54	55	56	57.5	58
20°	32	33	34	35	36	37	38	39	40	41	42	43	44.5	45.5	46.5	47.5	49	50	51	52	53	54	55	56	57
30°	31	32	33	34	35	36	37	38	39	40.5	41.5	42.5	43.5	44.5	45.5	46.5	48	49	50	51	52	53	54	55	56
40°	30	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42.5	44	45	46	47	48	49	50	51	52	53	54	55
50°	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
60°	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
70°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
80°	28	29	30	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42	43	44	45	46	47	48	49	50	51
90°	27	28	29	30	31	32	33	34	35	36	37	38	39	39.5	40.5	41.5	42.5	43.5	44.5	45	46	47	48	49	50
100°	26.5	27.5	28.5	29	30	31	32	33	34	35	36	37	38	39	40	41	42	42.5	43.5	44.5	45.5	46.5	47	48	49
110°	26	27	28	29	29.5	30.5	31.5	32.5	33.5	34.5	35	36	37	38	39	40	41	42	43	44	45	45.5	46.5	47	48
120°	25	26	27	28	29	30	31	32	33	34	34.5	35.5	36.5	37.5	38	39	40	41	42	43	44	45	45.5	46.5	47.5
130°	24.5	25.5	26.5	27.5	28.5	29	30	31	32	33	34	35	36	37	37.5	38.5	39.5	40.5	41	42	43	44	45	45.5	46.5
140°	24	25	26	27	28	29	29.5	30.5	31.5	32	33	34	35	36	37	38	38.5	39.5	40.5	41	42	43	44	45	46
150°	23.5	24.5	25	26	27	28	29	30	31	32	32.5	33.5	34.5	35	36	37	38	39	40	40.5	41.5	42	43	44	45

JOB SHEET #1

DIESEL FUELS
UNIT II

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Mixture of hydrocarbons in natural state

_____b. Compounds consisting of hydrogen and carbon

_____c. American Society of Testing Materials

_____d. ASTM classification of volatile fuel oils from kerosene to intermediate distillates

_____e. Class of distillate gas oils of lower volatility than kerosene

_____f. Ability of a liquid to change into a vapor when heated

1. No. 2-D diesel fuel
2. ASTM
3. Hydrocarbons
4. Crude oil
5. Volatility
6. No. 1-D diesel fuel

2. Arrange in order the operating principles that describe the diesel fuel combustion cycle.

_____a. Air only enters cylinder

_____b. Fuel-air ignites from heat of compression

_____c. Air is compressed

_____d. Fuel is sprayed into the combustion chamber

3. Match the properties of diesel fuel on the right with the correct definitions.

_____a. Amount of power fuel will provide when burned

_____b. Ratio of density of fuel (oil) to density of water

_____c. Oil temperature at which flammable vapor driven off will ignite from an open flame

_____d. Ease with which fuel will ignite expressed in numbers

1. Carbon residue
2. Viscosity
3. Ash
4. Pour point

_____e. Matter left after evaporation and chemical decomposition

_____f. Causes corrosion and deposit formations in an engine

_____g. Unburnable residue in the form of soluble metallic soaps and abrasive solids

_____h. Resistance of a liquid to flow

_____i. Lowest temperature at which fuel ceases to flow

5. Heat value
6. Specific gravity
7. Flash point
8. Sulfur content
9. Cetane number

4. List six crude oil by-products.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

5. Complete the following list of characteristics of diesel fuels.

a. Permits engine start at lower air temperatures

b. ______________________________

c. Reduces the rate of formation of varnish and carbon deposits

d. Eliminates combustion roughness or carbon knock

6. Name two grades of commercial diesel fuel that meet ASTM standards.

a. ______________________________

b. ______________________________

7. Distinguish between the cause of diesel ignition knock and the cause of gasoline ignition knock by placing an "X" next to the cause of diesel ignition knock.

_____a. Due to fuel burning too fast and uneven explosions

_____b. Due to fuel igniting too slowly

8. List three most likely causes of black smoke from a diesel exhaust.

   a. ______________________________

   b. ______________________________

   c. ______________________________

9. List two most likely causes of white smoke from a diesel exhaust.

   a. ______________________________

   b. ______________________________

10. List two important considerations when storing diesel fuel.

   a. ______________________________

   b. ______________________________

11. Select the methods and rules used to protect fuel quality by placing an "X" in the appropriate blanks.

   _____a. Store fuel in a galvanized tank

   _____b. Always drain the storage tank before refilling and clean the tank regularly

   _____c. Use tank formerly used for gasoline when needed

   _____d. Do not let the suction pipe to the fuel pump extend to the bottom of the storage tank

   _____e. Use an open container to transfer fuel from tank to machine

   _____f. Do not let water collect on top of fuel barrels or storage tanks

12. Select the number of feet required for safe spacing of storage tanks from buildings by placing the correct number in the appropriate blanks.

   _____a. Underground tanks

   _____b. Aboveground tanks

   1. 1 foot
   2. 2 feet
   3. 5 feet
   4. 30 feet
   5. 40 feet
   6. 50 feet

13. Demonstrate the ability to measure specific gravity of diesel fuel.

(Note: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

DIESEL FUELS
UNIT II
ANSWERS TO TEST

1. a. 4
   b. 3
   c. 2
   d. 6
   e. 1
   f. 5

2. a. 1
   b. 4
   c. 2
   d. 3

3. a. 5
   b. 6
   c. 7
   d. 9
   e. 1
   f. 8
   g. 3
   h. 2
   i. 4

4. Any six of the following:

   a. Natural gas
   b. High octane aviation gas
   c. Automotive gasoline
   d. Finished kerosene
   e. Domestic heating oil
   f. Hydrocarbon gases
   g. Industrial fuel oil (diesel fuel)
   h. Finished lubricating oils
   i. Wax (paraffin)
   j. Gas oil
   k. Coke
   l. Asphalt

5. b. Provides faster engine warm-up

6. a. No. 1-D
   b. No. 2-D

7. b

8. a. Faulty fuel injection
   b. Overfueling
   c. Restricted air intake

9. a. Unburned fuel
   b. Partially burned fuel

10. a. Keep fuel free of dirt and water
    b. Avoid gum deposits

11. b, d, f

12. a. 1
    b. 5

13. Performance skills evaluated to the satisfaction of the instructor.

ENGINE LUBRICANTS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to list functions of engine oils and match oil additives to their functions. The student should also be able to name oil contaminants and discuss ways to avoid oil contamination. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with lubricants with the correct definitions.
2. List four functions of engine oil.
3. Select the characteristics of a good engine oil.
4. Select true statements concerning oil ratings and classifications.
5. Complete a list of statements explaining the SAE viscosity number.
6. Select true statements concerning the API classification system.
7. Complete a list of characteristics of good synthetic oil.
8. Name five oil contaminants.
9. Match oil additives with their functions.
10. Select true statements about oil.
11. List general rules for selection and use of oils for best engine performance.
12. Complete a list of ways to avoid oil contamination.

ENGINE LUBRICANTS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Invite speakers from industry to talk on lubricants.

VII. Have students compare different oil classifications according to engine recommendations.

VIII. Discuss oil analysis and demonstrate taking samples.

IX. Take a field trip to an oil analysis lab.

X. Show film on oil contamination.

Example: "Lubricating Oils That Engines May Love"--John Deere

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  - A. Objective sheet
  - B. Information sheet
  - C. Transparency masters
    - 1. TM 1--SAE Viscosity
    - 2. TM 2--SAE Viscosity (Continued)
  - D. Test
  - E. Answers to test

II. References

A. *Fundamentals of Service: Fuels, Lubricants, and Coolants*. 4th ed. Moline, Illinois: Deere and Company, 1980.

B. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

ENGINE LUBRICANTS
UNIT III

INFORMATION SHEET

I. Terms and definitions

  A. Additives--Certain properties added to oil to provide extra performance

  B. Multi-grade oil--Oils compounded to behave as light oils at cold temperatures and heavy oils at warm temperatures

  C. SAE--Society of Automotive Engineers

  D. API--American Petroleum Institute

  E. MIL--Oil specifications prepared by the Ordnance Department of the Military Forces

  F. ASTM--American Society for Testing Materials

  G. Viscosity--A measure of the fluidity of an oil at a given temperature

  H. Viscometer--Instrument used to measure the length of time in seconds required for a specified volume of oil to flow through a small orifice when the oil is brought to a specified temperature

II. Functions of engine oil

  A. Reduces friction and wear

  B. Cools moving parts

  C. Helps seal cylinders

  D. Keeps parts clean

III. Characteristics of good engine oil

  A. Keeps a protective film on moving parts

  B. Resists breakdown at high temperatures

  C. Resists corrosion and rusting

  D. Prevents carbon build-up

  E. Prevents sludge formation

INFORMATION SHEET

F. Flows easily at low temperatures

G. Resists foaming

H. Resists breakdown after long use

IV. Oil ratings and classifications

A. SAE--Viscosity established by Society of Automotive Engineers

B. API--Service classification established by American Petroleum Institute

C. MIL--Specifications prepared by Ordnance Department of the U.S. Army, Navy, and Air Force

D. ASTM--Engine sequence tests whose procedures are adopted by the American Society for Testing Materials

V. SAE viscosity number (Transparencies 1 and 2)

A. Oils vary in viscosity as temperatures change

(NOTE: Oil becomes more fluid as temperatures increase and less fluid as temperatures decrease.)

B. Lighter oils for winter use are specified at 0°F and carry a 5w, 10w, or 20w symbol

(NOTE: Specifications are determined by time of flow through an instrument, such as a Saybolt viscometer, in seconds.)

C. Heavier oils are specified at 210°F and carry a 20, 30, 40, or 50 viscosity number

(NOTE: Compounded oils called multi-grade behave as light oils in cold temperatures and heavier oils at high temperatures, for example 10w-40 can replace four single grade oils.)

VI. API classification system

A. Joint effort of API, ASTM, and SAE organizations

B. Attempts to clarify oil specifications and oil qualities between the engine manufacturer, the petroleum industry, and the customer

VII. Characteristics of good synthetic oil

A. Keeps engine cleaner because it will not readily break down

B. Provides better hot weather protection as it will not thin out at high temperatures

C. Starts easily in cold weather because of the high viscosity index

INFORMATION SHEET

D. Minimizes fuel consumption because of the reduced formation of deposits on engine surfaces and the greater lubricity of the molecules of the base fluid

E. Extends drain intervals between oil changes

VIII. Oil contaminants

A. Foreign particles

B. Water

C. Antifreeze

D. Fuel

E. Oxidation

IX. Oil additives and their functions

(NOTE: Most oils already have these additives.)

A. Anti-corrosion--Helps prevent failure of alloy bearings from corrosive acids caused by combustion

B. Oxidation inhibitor--Prevents acid, varnish, and sludge formations

(NOTE: Oxidation causes oil to thicken.)

C. Anti-rust--Prevents rusting of metal parts during storage or downtime

D. Viscosity index improver--Helps oil give top lubricating protection at both high and low temperatures

E. Pour point depressant--Prevents wax crystals from congealing in cold weather and forming clumps

F. Extreme pressure--Assures lubrication where extreme pressures between close tolerances are encountered

G. Detergent-dispersant--Helps keep metal surfaces clean and prevents deposit formation

H. Foam inhibitor--Helps prevent air bubbles which would restrict lubrication

(NOTE: Fast circulation causes oil to foam.)

X. True statements about oil

A. Oil becomes unfit for further use as it absorbs contaminants and as additives are depleted

B. Multi-viscosity oils are not always preferred

INFORMATION SHEET

C. Black oil does not mean time for an oil change

D. Buy quality oil filters as recommended by machine operator's manual

E. Oil oxidation results in thicker oil

F. Using a light oil until consumption increases, and then switching to a heavier oil, is not a good practice

G. Following operator's manual recommendations is critical to insure good performance

XI. Selection and use of oils for best engine performance

A. Use brands which meet engine manufacturer's specifications

B. Drain and change at recommended intervals

C. Select oils which have been performance tested

D. Never mix oils of various MIL specifications

E. Bring engine up to normal operating temperature each time it is used

F. Keep oil containers covered, sealed, and protected to prevent contamination

XII. Ways to avoid oil contamination

A. Drain oil at recommended intervals

B. Use clean oil containers and work habits

C. Replace or clean filters before they become plugged

SAE Viscosity

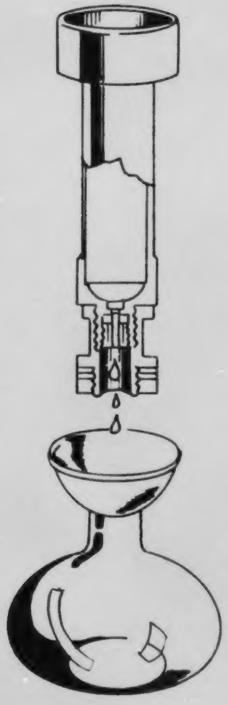
SAE CRANKCASE OIL CLASSIFICATION

SAE Viscosity Number	Time of Flow Through Saybolt Viscometer in Seconds			
	at 0°F.		at 210°F.	
	Min.	Max.	Min.	Max.
5W	—	6,000	—	—
10W	6,000 (Note A)	less than 12,000	—	—
20W	12,000 (Note B)	48,000	—	—
20	—	—	45	less than 58
30	—	—	58	less than 70
40	—	—	70	less than 85
50	—	—	85	110

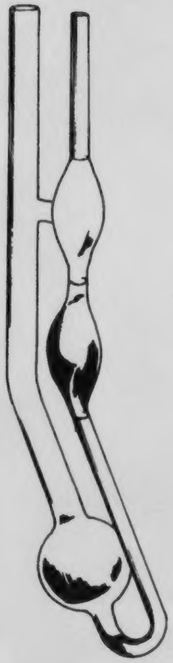
Note A. Minimum viscosity at 0°F may be waived provided viscosity at 210°F is not below 40 seconds, Saybolt Universal.

Note B. Minimum viscosity at 0°F may be waived provided viscosity at 210°F is below 45 seconds, Saybolt Universal.

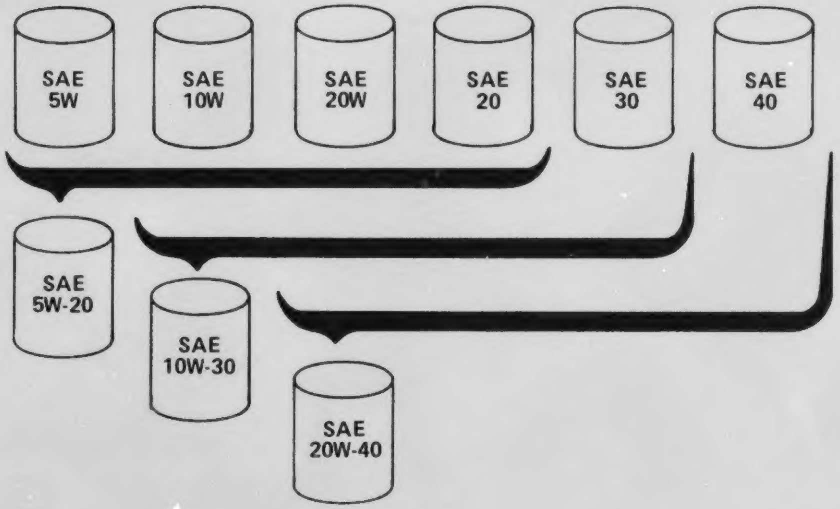
SAE Viscosity
(Continued)



Saybolt
Viscometer



Kinematic
Viscometer



SAE 5W
SAE 10W
SAE 20W
SAE 20
SAE 30
SAE 40

SAE 5W-20
SAE 10W-30
SAE 20W-40

A Multi-Viscosity Oil Can Replace Several Single-Viscosity Oils (When Recommended)

ENGINE LUBRICANTS
UNIT III

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____ a. Certain properties added to oil to provide extra performance

_____ b. Oils compounded to behave as light oils at cold temperatures and heavy oils at warm temperatures

_____ c. Society of Automotive Engineers

_____ d. American Petroleum Institute

_____ e. Oil specifications prepared by the Ordnance Department of the Military Forces

_____ f. American Society for Testing Materials

_____ g. A measure of the fluidity of an oil at a given temperature

_____ h. Instrument used to measure the length of time in seconds required for a specified volume of oil to flow through a small orifice when the oil is brought to a specified temperature

1. SAE
2. Viscosity
3. API
4. MIL
5. Viscometer
6. ASTM
7. Multi-grade oil
8. Additives

2. List four functions of engine oil.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

3. Select the statements which describe a characteristic of a good engine oil by placing an "X" in the appropriate blanks.

_____ a. Keeps a protective film on moving parts

_____ b. Resists breakdown at high temperatures

_____ c. Resists corrosion and rusting

______d. Prevents carbon build-up

______e. Prevents sludge formation

______f. Flows easily at low temperatures

______g. Flows easily at high temperature

______h. Resists foaming

______i. Resists breakdown after long use

4. Select true statements concerning oil ratings and classifications by placing an "X" in the appropriate blanks.

______a. SAE--Viscosity established by Society of Automotive Engineers

______b. API--Engine sequence tests whose procedures are adopted by the American Society for Testing Materials

______c. MIL--Specifications prepared by Ordnance Department of the U.S. Army, Navy, and Air Force

______d. ASTM--Service classification established by American Petroleum Institute

5. Complete the following list of statements explaining the SAE viscosity number.

a. Oils vary in viscosity as temperatures change

b. Lighter oils for winter use are specified at 0°F and carry a ____________________ ____________________ symbol

c. Heavier oils are specified at 210°F and carry a ______________________________ ________________________ viscosity number

6. Select true statements concerning the API classification system by placing an "X" in the appropriate blanks.

______a. Joint effort of API, ASTM, and SAE organizations

______b. Attempts to clarify oil specifications and oil qualities between the engine manufacturer, the petroleum industry, and the customer

7. Complete the following list of characteristics of good synthetic oil.

a. ____ because it won't readily break down

b. Provides better hot weather protection as it will not thin out at high temperatures

c. Starts in cold weather because of the ______________________________________

d. Minimizes fuel consumption because of the reduced formation of deposits on engine surfaces and the greater lubricity of the molecules of the base fluid

e. Extends drain intervals ____

8. Name five oil contaminants.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

9. Match the oil additives on the right with their functions.

_____a. Helps prevent failure of ally bearings from corrosive acids caused by combustion

_____b. Prevents acid, varnish, and sludge formations

_____c. Prevents rusting of metal parts during storage or downtime

_____d. Helps oil give top lubricating protection at both high and low temperatures

_____e. Prevents wax crystals from congealing in cold weather and forming clumps

_____f. Assures lubrication where extreme pressures between close tolerances are encountered

_____g. Helps keep metal surfaces clean and prevents deposit formation

_____h. Helps prevent air bubbles which would restrict lubrication

1. Anti-rust
2. Oxidation inhibitor
3. Anti-corrosion
4. Viscosity index improver
5. Pour point depressant
6. Extreme pressure
7. Foam inhibitor
8. Detergent-dispersant

10. Select true statements about oil by placing an "X" in the appropriate blanks.

_____a. Oil becomes unfit for further use as it absorbs contaminants and as additives are depleted

_____b. Multi-viscosity oils are not always preferred

_____c. Black oil does not mean time for an oil change

_____d. Buy quality oil filters as recommended by machine operator's manual

_____e. Oil oxidation results in thicker oil

_____f. Using a light oil until consumption increases, and then switching to a heavier oil, is not a good practice

_____g. Following operator's manual recommendations is critical to insure good performance

11. List five general rules for selection and use of oils for best engine performance.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

12. Complete the following list of ways to avoid oil contamination.

    a. Drain oil at recommended intervals

    b. ______________________________

    c. Replace or clean filters before they become plugged

ENGINE LUBRICANTS
UNIT III

ANSWERS TO TEST

1. a. 8
   b. 7
   c. 1
   d. 3
   e. 4
   f. 6
   g. 2
   h. 5

2. a. Reduces friction and wear
   b. Cools moving parts
   c. Helps seal cylinders
   d. Keep parts clean

3. a, b, c, d, e, f, h, i

4. a, c

5. b. 5w, 10w, or 20w
   c. 20, 30, 40, or 50

6. a, b

7. a. Keeps engine cleaner
   c. High viscosity index
   e. Between oil changes

8. a. Foreign particles
   b. Water
   c. Antifreeze
   d. Fuel
   e. Oxidation

9. a. 3
   b. 2
   c. 1
   d. 4
   e. 5
   f. 6
   g. 8
   h. 7

10. a, b, c, d, e, f, g

11. Any five of the following:

    a. Use brands which meet engine manufacturer's specifications
    b. Drain and change at recommended intervals
    c. Select oils which have been performance tested
    d. Never mix oils of various MIL specifications
    e. Bring engine up to normal operating temperature each time it is used
    f. Keep oil containers covered, sealed, and protected to prevent contamination

12. b. Use clean oil containers and work habits

COOLANTS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the advantages and disadvantages of water as a coolant. The student should also be able to discuss the requirements of a good antifreeze and list the preventive maintenance procedures to follow in maintaining a cooling system. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with coolants with the correct definitions.
2. Name two types of cooling systems used on modern engines.
3. Match the parts of a liquid cooling system with the correct functions.
4. Complete a list of statements concerning the parts of a marine cooling system and their correct functions.
5. Complete a list of statements concerning the parts of an air cooled engine and their correct functions.
6. List advantages of water as a coolant.
7. List disadvantages of water as a coolant.
8. List requirements of a good antifreeze.
9. Name two types of antifreeze used most in modern engines.
10. Match the coolant with the temperature at which it boils.
11. List preventive maintenance procedures to follow in maintaining a cooling system.

COOLANTS
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures for measuring specific gravity in a cooling system.

VII. Discuss cooling system conditioners.

VIII. Discuss harmful effects of antifreeze on livestock.

IX. Have students make a chart with different size cooling systems.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Parts of a Liquid Cooling System

    2. TM 2--Coolant Filter and Conditioner

    3. TM 3--Parts of a Marine Cooling System

    4. TM 4--Air Cooled Diesel Engine

  D. Test

  E. Answers to test

II. References:

  A. *Fundamentals of Service: Fuels, Lubricants, and Coolants*. 4th ed. Moline, Illinois: Deere and Co., 1980.

  B. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

COOLANTS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Inhibitor--Material used in coolants to restrict or prevent corrosion of metal parts

B. Antifreeze--Material added to coolant to prevent freezing

C. Coolant--Liquid that absorbs and transfers heat to maintain normal engine operating temperature

D. Permanent antifreeze--Liquid solution which contains properties that will not readily boil away

II. Types of cooling systems used on modern engines

A. Air

B. Liquid

III. Parts of a liquid cooling system and their functions (Transparencies 1 and 2)

A. Radiator--Releases heat to atmosphere; reservoir for enough liquid coolant to operate engine

B. Expansion tank--Separate tank in cooling system that allows for heat expansion of coolant

C. Pressure cap--Relieves pressure from too much heat; lets in air pressure as liquid cools

(NOTE: A pressurized cooling system raises the boiling temperatures of coolants about 2° for each pound of pressure.)

D. Fan--Forces cooling air through radiator core to more quickly dissipate heat

E. Fan belt--Transmits power from engine crankshaft to drive fan and water pump

F. Water pump--Circulates coolant through the system

G. Thermostat--Controls the flow of coolant to radiator to maintain correct operating temperatures

H. Hoses--Flexible connections between engine and other parts of cooling system

I. Coolant--Medium which carries away excess heat from engine

J. Coolant filter--Used in some engines to soften the water and remove dirt

INFORMATION SHEET

IV. Parts of a marine cooling system and their functions (Transparency 3)

- A. Expansion tank--Provides a means of filling the engine cooling system, as well as space for expansion of the coolant as its temperature rises
- B. Heat exchanger--Consists of a series of vertical cells contained within a rectangular cage, with a header at one end and a circular water outlet at the opposite end
- C. Raw water pump--Raw water is circulated through the heat exchanger by a positive displacement pump

V. Parts of an air cooled engine and their functions (Transparency 4)

- A. Direct cooling system--Forces air by the cylinders at all times while engine is running
- B. Fin head and cylinder blocks--Allow cool air to go by the head and cylinders to draw heat away
- C. Aerodynamic intake port--Brings air into chambers in a swirling motion for more efficient combustion process

VI. Advantages of water as a coolant

- A. Plentiful and cheap
- B. Absorbs heat well
- C. Circulates freely
- D. Harmless to handle

VII. Disadvantages of water as a coolant

- A. Will freeze at 32°F
- B. Can corrode metal parts
- C. Can leave deposits
- D. Will evaporate

VIII. Requirements of a good antifreeze

- A. Prevents freezing
- B. Inhibits rust and corrosion
- C. Chemically stable

INFORMATION SHEET

- D. Nonconductor of electricity
- E. Flows readily at all temperatures
- F. Conducts heat readily
- G. Resists foaming

IX. Types of antifreeze used most in modern engines

- A. Alcohol base
- B. Ethylene glycol base

X. Boiling temperature of coolants

- A. Alcohol base antifreeze--180°F
- B. Water--212°F
- C. Ethylene glycol base antifreeze--223°F

XI. Preventive maintenance procedures

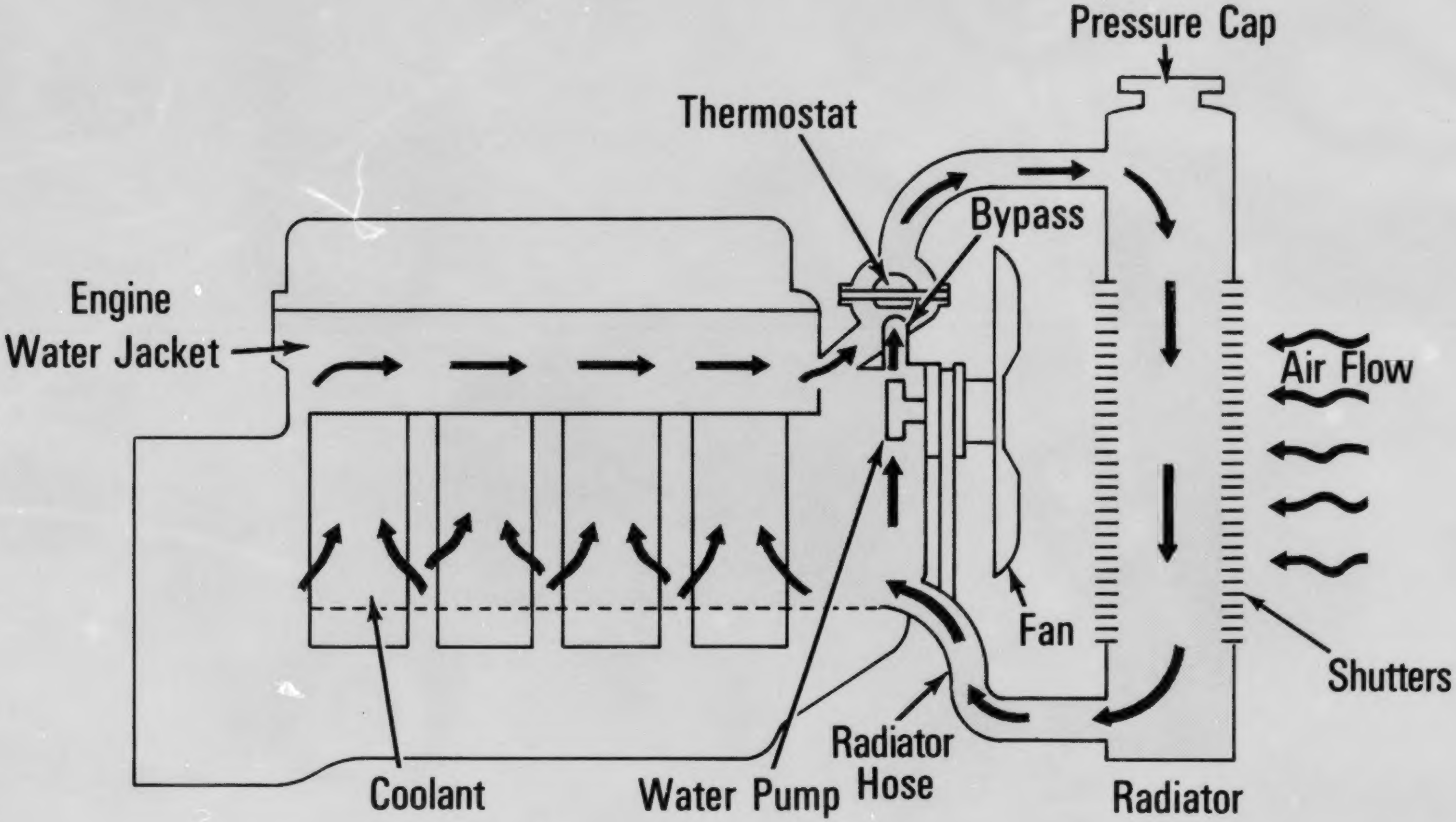
- A. Inspect for system deterioration

  (NOTE: Pressure test the cooling system.)

  (CAUTION: Do not exceed pressure cap limits.)
- B. Prevent corrosion and deposits
- C. Flush and clean system periodically
- D. Lubricate water pump and fan, as required
- E. Allow a hot engine to idle a few minutes before shutting it down

  (NOTE: Idle speed allows temperatures of parts to equalize and prevents after boil of coolant.)
- F. Check coolant as recommended in operator's manual

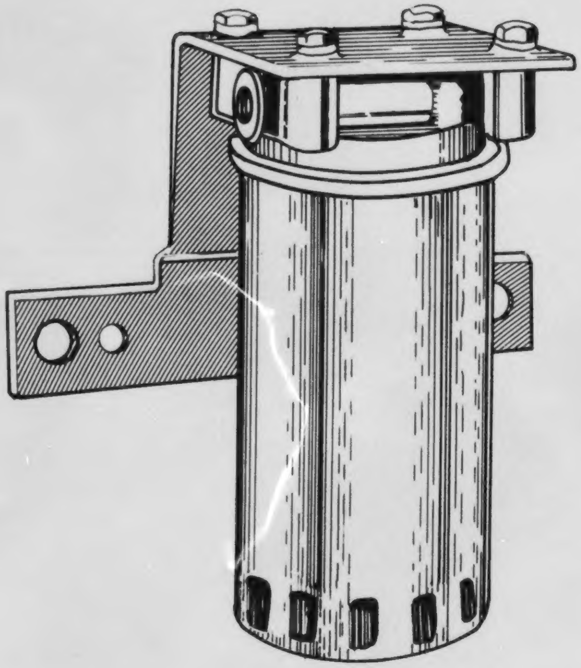
Parts of a Liquid Cooling System


Pressure Cap
Thermostat
Bypass
Engine
Water Jacket
Air Flow
Fan
Shutters
Radiator
Hose
Coolant
Water Pump
Radiator

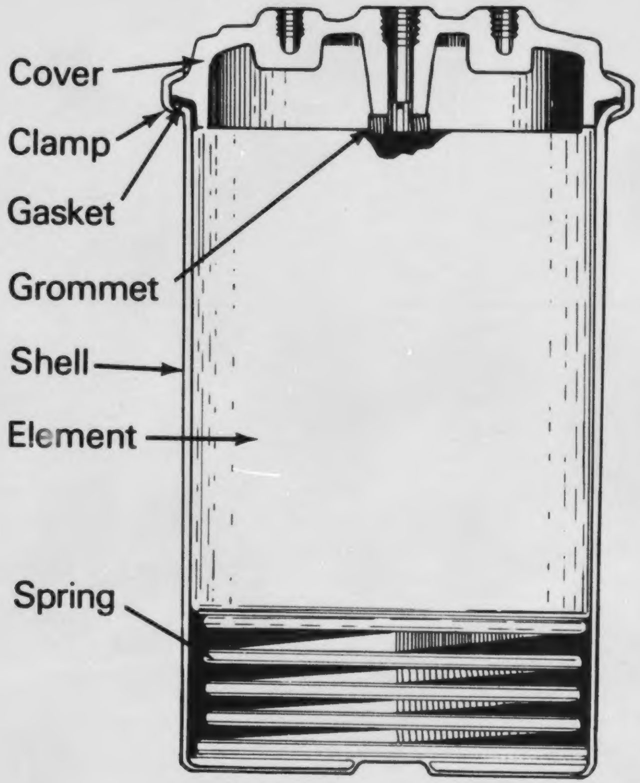
333

334

Coolant Filter and Conditioner



External View


Cover
Clamp
Gasket
Grommet
Shell
Element
Spring

Internal View

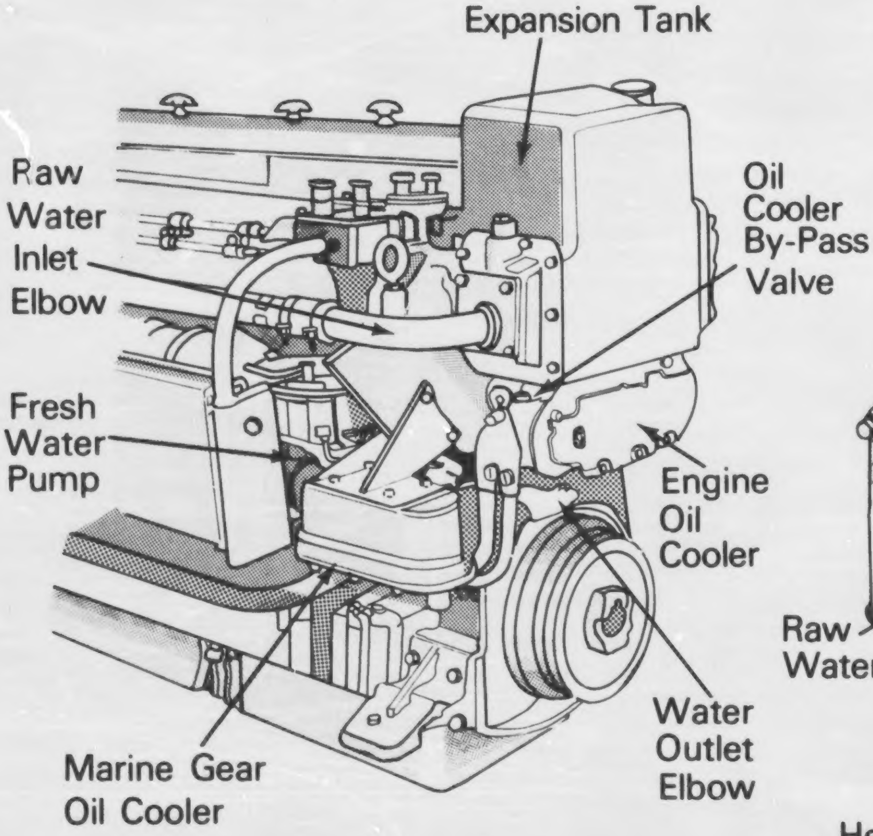
336

TM 2

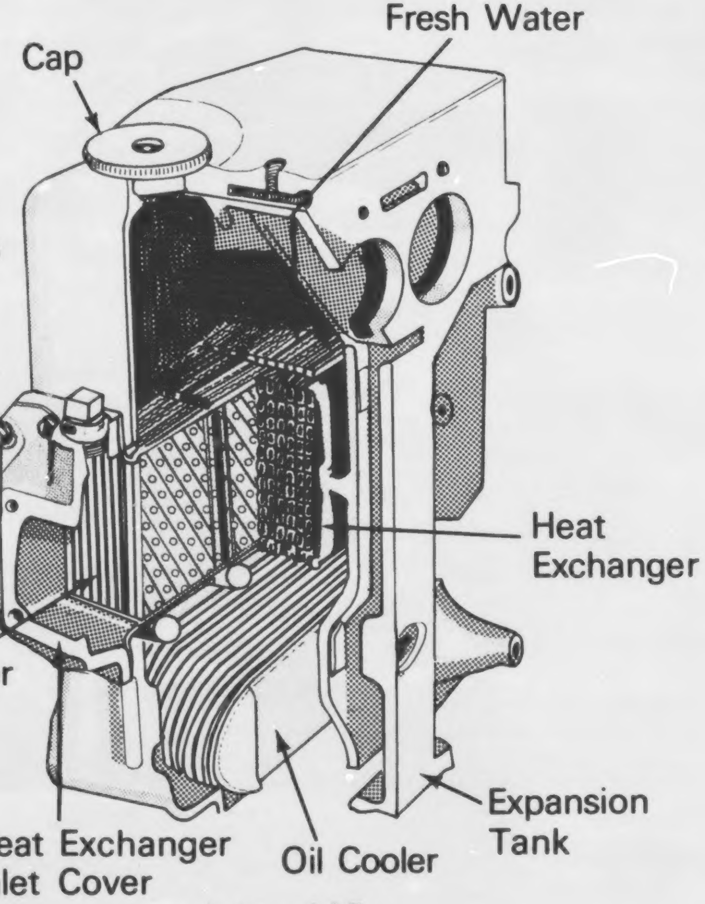
335

D:F - 97-B

Parts of a Marine Cooling System

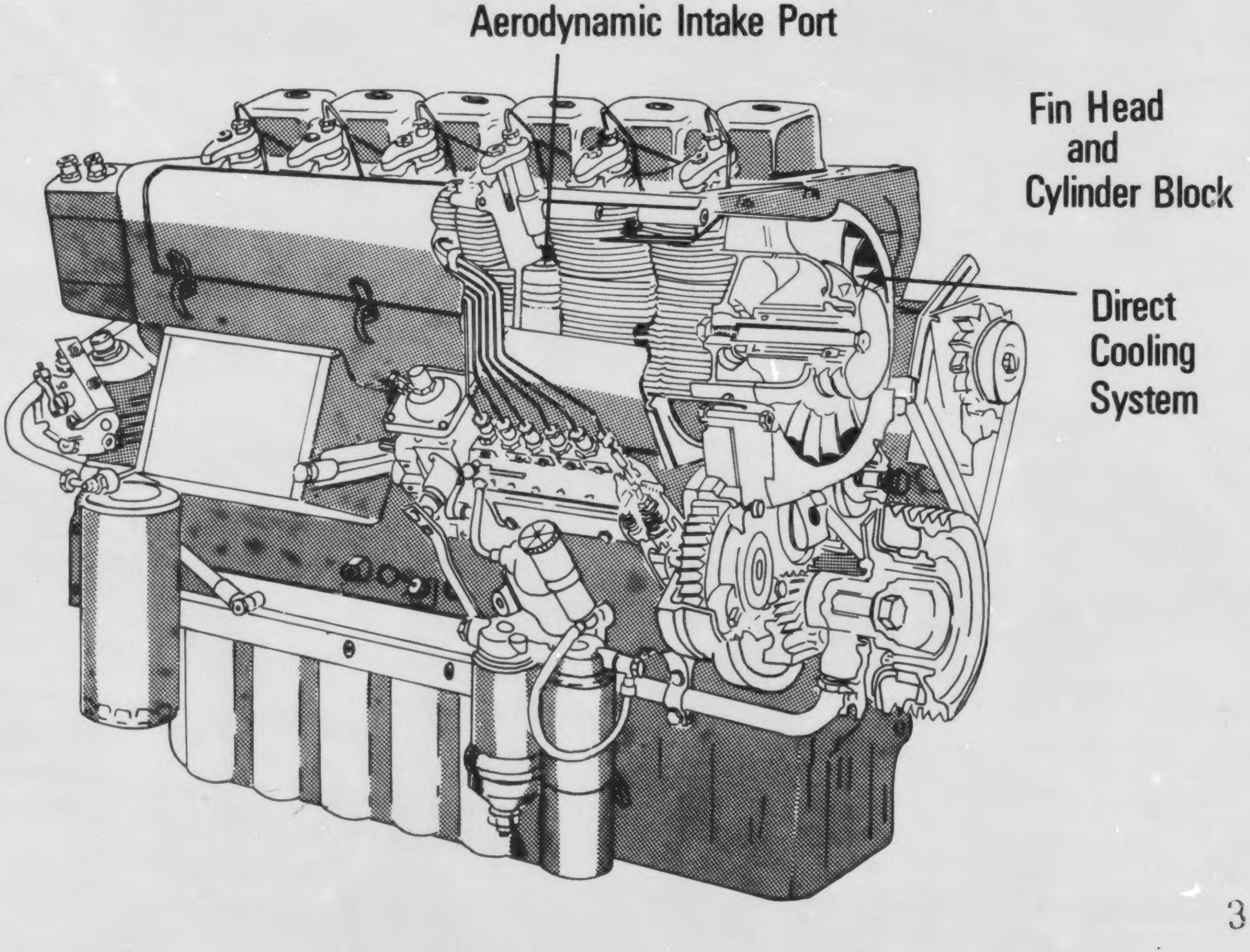

Expansion Tank
Raw Water Inlet Elbow
Oil Cooler By-Pass Valve
Fresh Water Pump
Engine Oil Cooler
Water Outlet Elbow
Marine Gear Oil Cooler

External View


Cap
Fresh Water
Heat Exchanger
Raw Water
Expansion Tank
Heat Exchanger Inlet Cover
Oil Cooler

Internal View

Air Cooled Diesel Engine


Aerodynamic Intake Port
Fin Head and Cylinder Block
Direct Cooling System

COOLANTS
UNIT IV

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Material used in coolants to restrict or prevent corrosion of metal parts

_____b. Material added to coolant to prevent freezing

_____c. Liquid that absorbs and transfers heat to maintain normal engine operating temperature

_____d. Liquid solution which contains properties that will not readily boil away

1. Permanent antifreeze
2. Antifreeze
3. Coolant
4. Inhibitor

2. Name two types of cooling systems used on modern engines.

a. ______________________________

b. ______________________________

3. Match the parts of a liquid cooling system on the right with the correct functions.

_____a. Releases heat to atmosphere; reservoir for enough liquid coolant to operate engine

_____b. Separate tank in cooling system that allows for heat expansion of coolant

_____c. Relieves pressure from too much heat; lets in air pressure as liquid cools

_____d. Forces cooling air through radiator core to more quickly dissipate heat

_____e. Circulates coolant through the system

_____f. Transmits power from engine crankshaft to drive fan and water pump

_____g. Controls the flow of coolant to radiator to maintain correct operating temperatures

_____h. Flexible connections between engine and other parts of cooling system

1. Thermostat
2. Pressure cap
3. Fan
4. Radiator
5. Coolant
6. Fan belt
7. Water pump
8. Hoses
9. Coolant filter
10. Expansion tank

_____i. Medium which carries away excess heat from engine

_____j. Used in some engines to soften the water and remove dirt

4. Complete the following list of statements concerning the parts of a marine cooling system and their functions.

   a. ________________--Provides a means of filling the engine cooling system, as well as space for expansion of the coolant as its temperature rises

   b. Heat exchanger--Consists of a series of ________________ contained within a rectangular cage, with a header at one end and a circular water outlet at the opposite end

   c. Raw water pump--Raw water is circulated through the heat exchanger by a ______________________________

5. Complete the following list of statements concerning the parts of an air cooled engine and their functions.

   a. Direct cooling system--Forces air by the cylinder at all times ______________ ______________________________

   b. Fin head and cylinder blocks--Allow cool air to go by the head and cylinders to ____________________________

   c. ________________________--Brings air into chambers in a swirling motion for more efficient combustion process

6. List three advantages of water as a coolant.

   a. ____

   b. ____

   c. ____

7. List three disadvantages of water as a coolant.

   a. ____

   b. ____

   c. ____

8. List five requirements of a good antifreeze.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

9. Name two types of antifreeze used most in modern engines.

   a. ______________________________

   b. ______________________________

10. Match the coolant on the right with the temperature at which it boils.

_____	a. 223°F	1. Alcohol base antifreeze
_____	b. 180°F	2. Water
_____	c. 212°F	3. Ethylene glycol base antifreeze

11. List four preventive maintenance procedures to follow in maintaining a cooling system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

COOLANTS
UNIT IV

ANSWERS TO TEST

1. a. 4
   b. 2
   c. 3
   d. 1

2. a. Air
   b. Liquid

3. a. 4
   b. 10
   c. 2
   d. 3
   e. 7
   f. 6
   g. 1
   h. 8
   i. 5
   j. 9

4. a. Expansion tank
   b. Vertical cells
   c. Positive displacement pump

5. a. While engine is running
   b. Draw heat away
   c. Aerodynamic intake port

6. Any three of the following:

   a. Plentiful and cheap
   b. Absorbs heat well
   c. Circulates freely
   d. Harmless to handle

7. Any three of the following:

   a. Will freeze at 32°F
   b. Can corrode metal parts
   c. Can leave deposits
   d. Will evaporate

8. Any five of the following:

   a. Prevents freezing
   b. Inhibits rust and corrosion
   c. Chemically stable
   d. Nonconductor of electricity
   e. Flows readily at all temperatures
   f. Conducts heat readily
   g. Resists foaming

9. a. Alcohol base
   b. Ethylene glycol base

10. a. 3
    b. 1
    c. 2

11. Any four of the following:

    a. Inspect for system deterioration
    b. Prevent corrosion and deposits
    c. Flush and clean system periodically
    d. Lubricate water pump and fan, as required
    e. Allow a hot engine to idle a few minutes before shutting it down
    f. Check coolant as recommended in operator's manual

BEARINGS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to name types of bearings and list their functions. The student should also be able to list factors influencing the distribution of lubricant to the bearings, list causes of bearing failure and demonstrate correct procedures for removal and installation of plain and anti-friction bearings. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with bearings with the correct definitions.
2. List four functions of bearings.
3. Name two basic types of bearings.
4. Distinguish between axial and radial load forces on bearings.
5. Match the types of bearings with the advantages and disadvantages.
6. Match the illustrations of plain bearings with the correct names.
7. List materials from which bearings may be constructed.
8. List three factors influencing the distribution of lubricant to the bearings.
9. Name common methods of lubricating bearings.
10. List causes of bearing failure in plain bearings.
11. List four reasons for bearing crush.
12. Name three types of anti-friction bearings.
13. List three conditions that determine the load carrying capacity of anti-friction bearings.
14. Name four types of ball bearing races.
15. List four designs of ball bearings.

16. List five types of roller bearings.

17. Name two types of needle bearings.

18. Select true statements concerning mountings for anti-friction bearings.

19. Select bearing maintenance tips.

20. Demonstrate the ability to:

    a. Remove and install a plain bearing.

    b. Remove and install an anti-friction bearing.

    c. Check preload bearing setting, spring scale method.

BEARINGS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Discuss typical adjusting (preloading) devices for tapered roller bearings to include slotted hex nut and cotter pin, lock nuts and torqued washer, shims, and threaded cup follower.

VIII. Have students show the different layers in a split bearing.

IX. Identify different types of bearings from a display.

X. Show film on application and/or installation of bearings.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Basic Types of Bearings
    2. TM 2--Types of Anti-Friction Bearings
    3. TM 3--Load Forces
    4. TM 4--Types of Plain Bearings
    5. TM 5--Oil Groove Design
    6. TM 6--Methods of Bearing Lubrication

7. TM 7--Causes of Bearing Failure
8. TM 8--Types of Ball Bearing Races
9. TM 9--Ball Bearing Designs
10. TM 10--Basic Types of Roller and Needle Bearings
11. TM 11--Typical Ball Bearing Mountings
12. TM 12--Typical Roller Bearing Mountings
13. TM 13--Typical Needle Bearing Mountings

D. Job sheets

1. Job Sheet #1--Remove and Install a Plain Bearing
2. Job Sheet #2--Remove and Install an Anti-Friction Bearing
3. Job Sheet #3--Check Preload Bearing Setting, Spring Scale Method

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Bearings and Seals.* 3rd ed. Moline, Illinois: Deere and Company, 1980.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

BEARINGS
UNIT V

INFORMATION SHEET

I. Terms and definitions

   A. Friction--Resistance to motion between two bodies in contact

   B. Radial load--Force is directed sideways or perpendicular to the shaft

   C. Axial load--Force is directed endways or horizontal to shaft

   D. Races--Two hardened steel rings

   E. Plastigage--Plastic thread which "crushes" to the exact clearance when measuring bearing clearance

   F. Babbit--Alloy of lead, tin, antimony, and other metals

   G. Plain bearing--Supporting surface for a wheel or shaft that provides a sliding contact between the mating surfaces

   (NOTE: Plain bearings are also called bushings.)

   H. Bearing crush--Each half of the bearing extends one or two thousandths of an inch beyond the bearing seat bore

   I. Anti-friction bearing--Supporting surface for a wheel or shaft that provides a rolling contact between mating surfaces

   J. Preloading--Adjustment of anti-friction bearing after being secured in the mounting

II. Functions of bearings

   A. Support the moving part

   B. Reduce friction

   C. Reduce wear

   D. Provide a replaceable wear surface

III. Basic types of bearings (Transparencies 1 and 2)

   A. Plain bearings

   B. Anti-friction bearings

INFORMATION SHEET

IV. Load forces on bearings (Transparency 3)

  A. Axial load forces are those forces directed endways

  (NOTE: Thrust bearings are used to support the endways force.)

  B. Radial load forces are those forces directed sideways or perpendicular to the shaft

V. Advantages and disadvantages of plain bearings and anti-friction bearings

  A. Plain bearings (bushings)

    1. Advantages

      a. Require little space

      b. Low in cost

      c. Quiet operation

      d. Rigid construction

    2. Disadvantages

      a. High friction operation

      b. Require more frequent lubrication because they cannot be packed

  B. Anti-friction bearings

    1. Advantages

      a. Low friction operation

      b. Can be packed to reduce frequency of lubrication

      c. More versatile, many designs

    2. Disadvantages

      a. Require more space

      b. Noisier operation

      c. Higher cost

      d. Less rigidity

INFORMATION SHEET

VI. Types of plain bearings (Transparency 4;

  A. Solid bearing or sleeve

  B. Split bearing, rolled type

  C. Thrust bearing

  D. Split bearing with steel back lined with bronze or babbit

  E. Split type constructed of wood, plastic, or rubber

  F. Split bearing used for engine crankshaft

  G. Solid bearing with fluted rubber structure

VII. Materials from which bearings may be constructed

  A. Wood

  B. Cast iron

  C. Soft steel

  D. Hard steel

  E. Copper, brass, and bronze

  F. Copper, lead

  G. Babbit

  H. Aluminum

  I. Plastic

  J. Rubber

VIII. Factors influencing the distribution of lubricant to the bearings (Transparency 5)

  A. Oil grooves

  B. Bearing clearance

  C. Bearing surface compatibility

  (NOTE: Bearing surface compatibility is determined by viscosity of the lubricant, speed of shaft rotation, and smoothness of the mating surfaces.)

INFORMATION SHEET

IX. Methods of lubricating bearings (Transparency 6)

   A. Oil can

   B. Grease gun

   C. Central grease system

      (NOTE: One plunger lubricates several grease fittings.)

   D. Oil bath splash

   E. Pressure feed system

X. Causes of bearing failure in plain bearings (Transparency 7)

   A. Dirt

   B. Lack of lubrication

   C. Improper assembly

      (NOTE: Improper assembly may result in too little or too much bearing crush, improper bearing clearance, or mislocated oil hole.)

   D. Misalignment

   E. Overloading

   F. Corrosion

XI. Reasons for bearing crush

   A. Greater heat dissipation

   B. Insert is forced to seat solidly

   C. Insures that the bearings remain round

   D. Avoids any possible movement of the bearing in the seat

   (NOTE: The amount of crush must not be excessive (.001" or .002") or the insert will be distorted when the cap is tightened. The bearing will buckle, and will result in increased friction and heat.)

XII. Types of anti-friction bearings (Transparency 2)

   A. Ball

   B. Roller

   C. Needle

INFORMATION SHEET

XIII. Conditions that determine load carrying capacity of anti-friction bearings

  A. Size of bearing

  B. Number of rolling elements

  C. Type of race

XIV. Types of ball bearing races (Transparency 8)

  A. Conrad

  B. Full type

  C. Split race

  D. Angular contact

XV. Designs of ball bearings (Transparency 9)

  A. Radial load

  B. Radial and thrust load

  C. Self-aligning, radial load

  D. Thrust load

XVI. Types of roller bearings (Transparency 10)

  A. Radial load, straight roller

  B. Radial and thrust load, tapered roller

  C. Self-aligning, radial and thrust load, spherical roller

  D. Self-aligning, radial and thrust load, concave roller

  E. Thrust load

XVII. Types of needle bearings (Transparency 10)

  A. Radial load

  B. Thrust load

INFORMATION SHEET

XVIII. Mountings for anti-friction bearings (Transparencies 11, 12, and 13)

A. Shape must not be distorted

B. Rolling elements must not be bound

C. Inner and outer races must be aligned

(NOTE: This is not necessary with self-aligning bearings.)

D. Axis of each bearing must be aligned with the other

(NOTE: The above condition applies when two or more bearings are mounted on the same shaft.)

E. Usually mounted with one race a press fit and the other a push fit

(NOTE: Normally the press fit race is pressed onto or into the rotating part and the push fit onto or into the stationary part. This rule of thumb is not true in every situation. Large bearings, tremendous loads, and high speeds may require both races to be pressed into place.)

F. Seals are used to retain lubricant and exclude dirt

XIX. Bearing maintenance tips

A. Work with clean approved tools, in clean surroundings

B. Clean outside of housings before exposing bearings

C. Handle bearings with clean, dry hands

D. Work on a metal or metal covered bench

E. Treat a used bearing as carefully as a new one, until the used one is proven to be defective

F. Use clean solvents and flushing oils

G. Lay bearings out on a clean surface

H. Protect disassembled bearings from dirt and moisture

I. Wipe bearings, if necessary, only with clean, lint-free rags

J. Keep bearings wrapped in oil-proof paper when not in use

K. Thoroughly clean the inside of housings before installing bearings

INFORMATION SHEET

L. Install new bearings as they come from the package, without washing, if they are received in a sealed container

M. Keep lubricants clean when applying them, and cover the containers when not in use

N. Don't spin uncleaned or dry bearings

O. Don't spin any bearing with compressed air

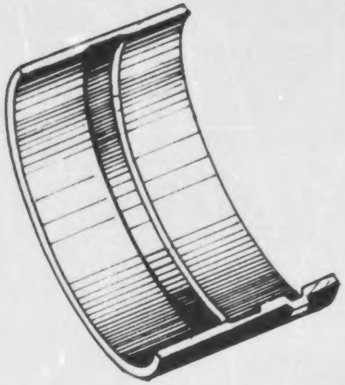
P. Don't use the same container for both cleaning and final rinse of used bearings

Q. Don't use gasolines

(CAUTION: The fumes may be injurious to health, as well as a fire hazard.)

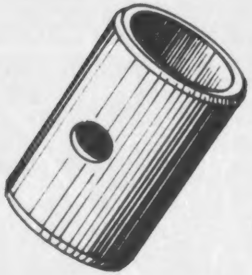
R. Don't use incorrect type or amount of lubricant

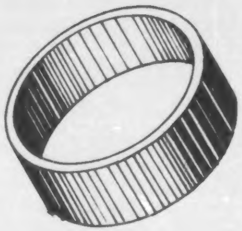
Basic Types Of Bearings



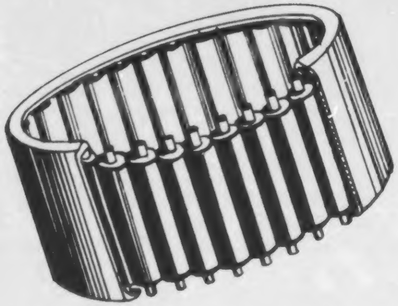
Split Bearing

Plain Bearings (Bushings)



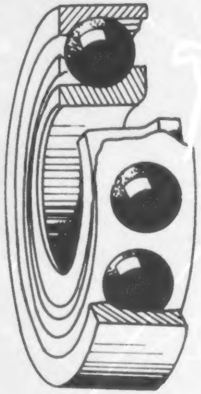


Plain Bearings

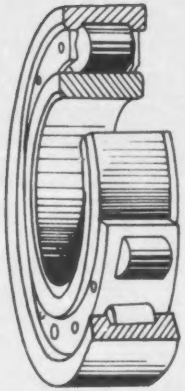


Needle Bearing

Anti-Friction Bearings

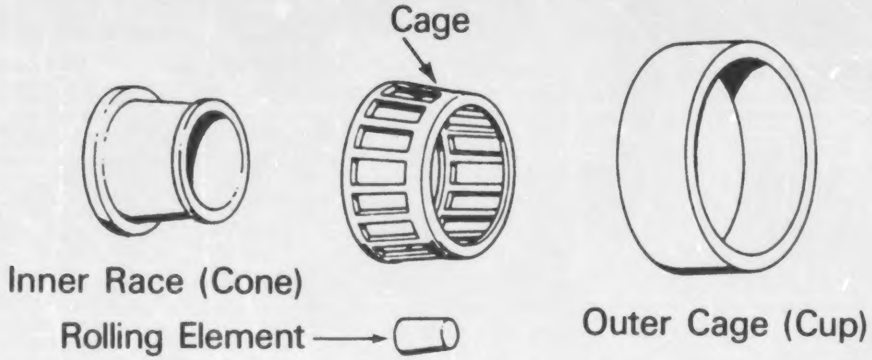


Ball Bearing

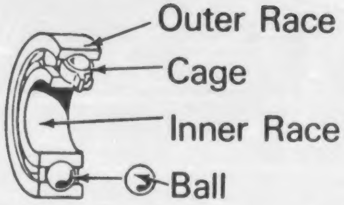


Rolier Bearing

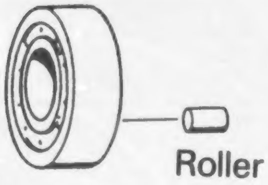
Types of Anti-Friction Bearings


Cage
Inner Race (Cone)
Rolling Element
Outer Cage (Cup)

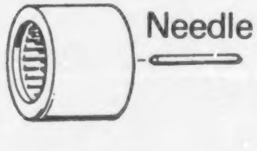
Tapered Roller Bearing


Outer Race
Cage
Inner Race
Ball

Ball Bearing

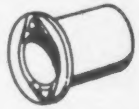


Straight Roller Bearing



Needle Bearing

Friction Bearing

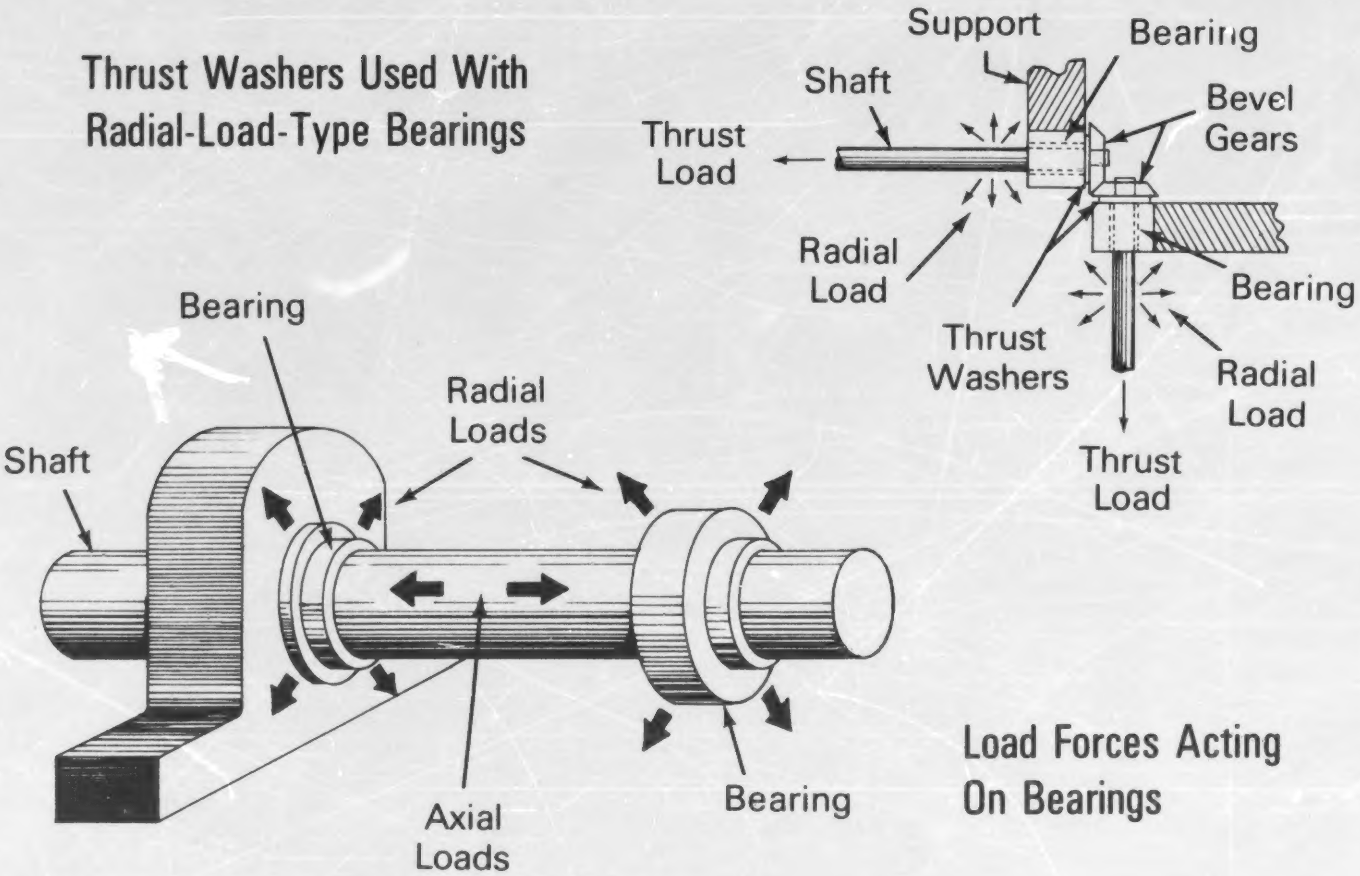


Bronze Bearing

TM 2

D:F - 123-B

Load Forces



Thrust Washers Used With Radial-Load-Type Bearings

Support
Bearing
Shaft
Bevel Gears
Thrust Load
Radial Load
Thrust Washers
Bearing
Radial Load
Thrust Load

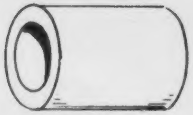
Load Forces Acting On Bearings

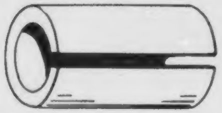
Bearing
Radial Loads
Shaft
Axial Loads
Bearing

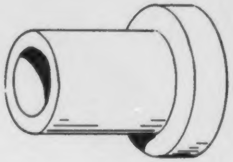
TM 3

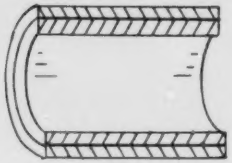
D:F - 125-B

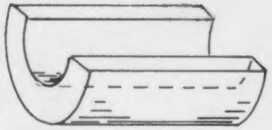
Types of Plain Bearings

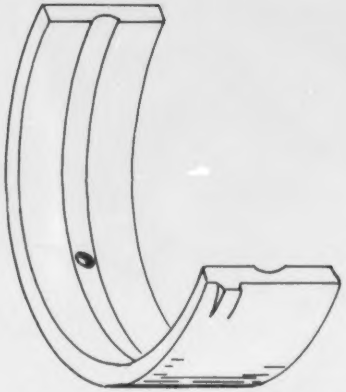

Solid Bearing or Sleeve

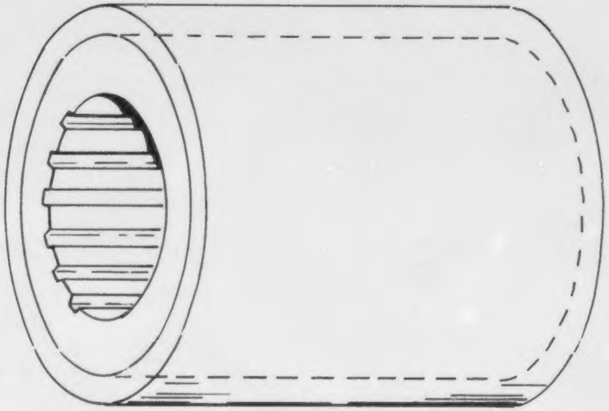

Split Bearing, Rolled Type


Thrust Bearing


Split Bearing with Steel Back Lined with Bronze or Babbit


Split Type Constructed of Wood, Plastic, or Rubber

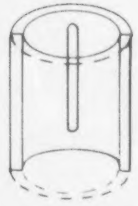

Split Bearing Used for Engine Crankshaft


Solid Bearing with Fluted Rubber Structure

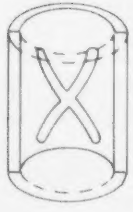
TM 4

D:F - 127-B

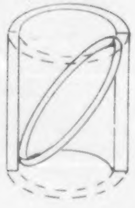
Oil Groove Design



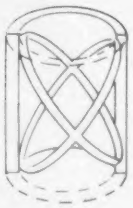
Used in
General
Applications



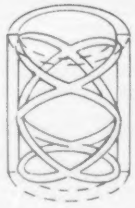
Also Used
in General
Applications



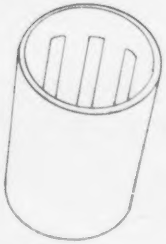
Used When Oil
is Supplied Near
End of Bearing



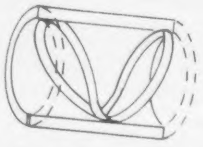
Used for
Grease
Lubrication



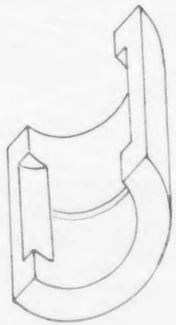
Also Used
for Grease
Lubrication



Used for
Pulsating Loads
with Limited
Shaft Rotation

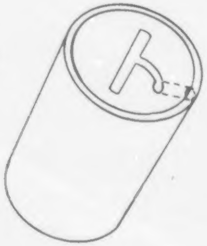


Used for
Fractional
Horsepower
Motors

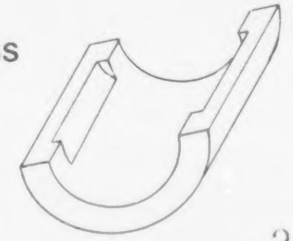


Circumferential
Groove and
Chamfered Recess
Improves Oil Film
Cooling. Used in
Engine Bearings.

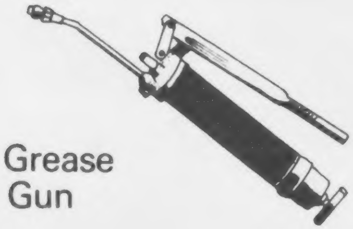
Feeder
Groove and Axial
Distributing
Groove Used
for Large, Slow
Speed Bearings



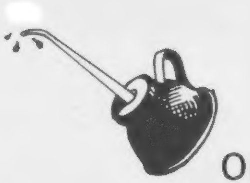
Chamfered Recess
in Split Bearing
Distributes Oil
Along Shaft.
Used in Engines.



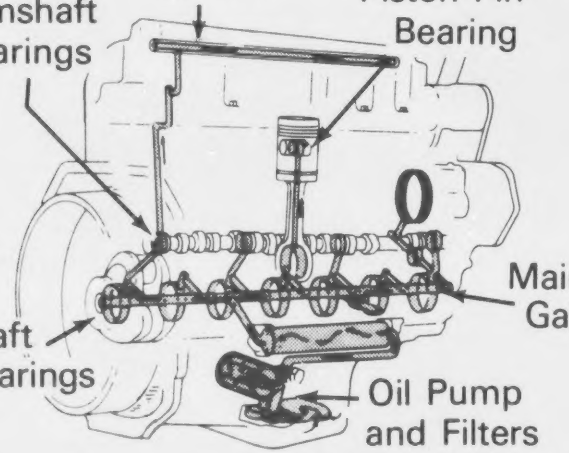
Methods of Bearing Lubrication

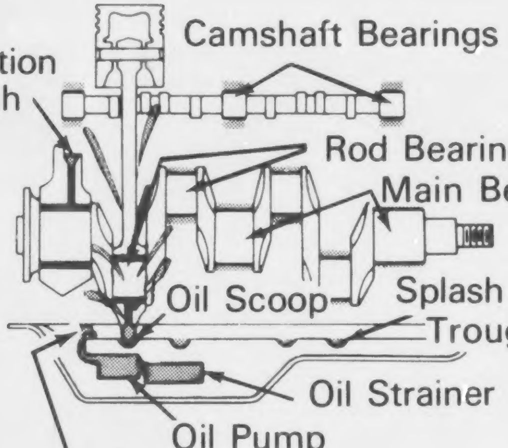


Two Types of Hand Lubrication



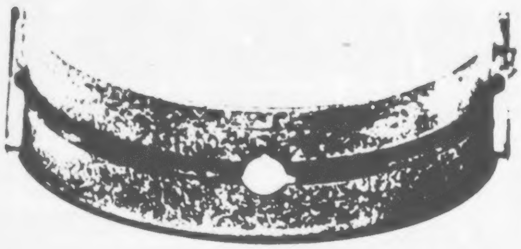
Pressure-Feed Oil System in a Typical Engine


Tappet Lever
Shaft
Camshaft
Bearings
Piston Pin
Bearing
Main Oil
Gallery
Crankshaft
Main Bearings
Oil Pump
and Filters

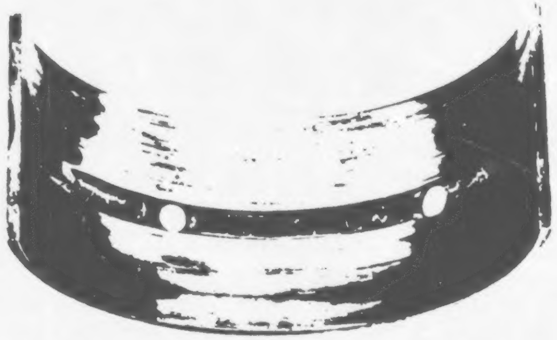

Camshaft Bearings
Oil Collection
Trough
Rod Bearings
Main Bearings
Oil Scoop
Splash Pan
Troughs
Oil Strainer
Oil Pump
Oil Supply to
Splash Pan

Circulating Splash System

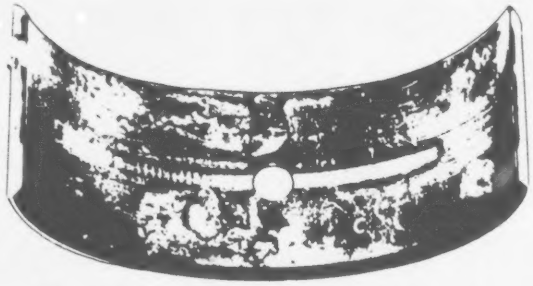
Causes of Bearing Failure



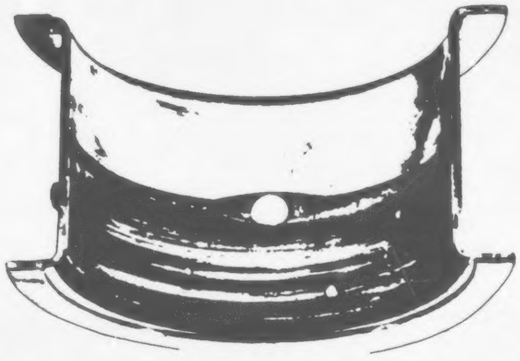
Damage From Dirt
Embedded In Bearing



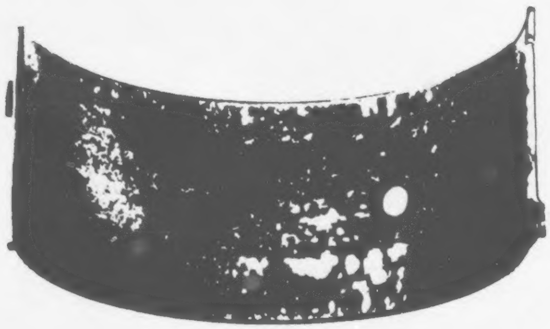
Oil Starvation Caused This Damage



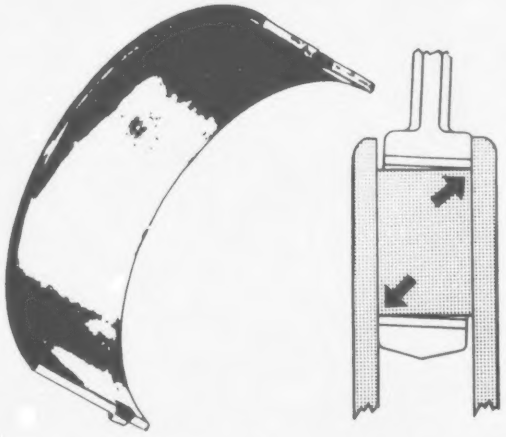
Bearing Fatigue Caused By
Overloading and Heat



Wear On One Edge of Bearing
Caused by Tapered Journals

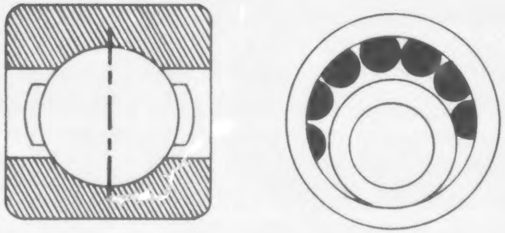


Corrosion From Acid
Formation In Oil



Excessive Wear Caused
by a Bent Connecting Rod

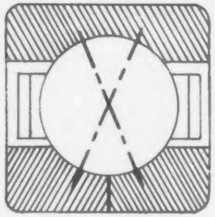
Types of Ball Bearing Races



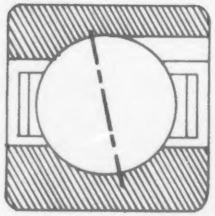
Conrad Bearing

Inner Race In Eccentric Position For Loading. Good For Both Radial And Thrust Loads.

Split Race Bearing



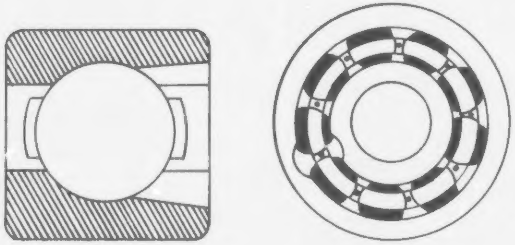
Inner Race Is Center-Cut. Good For Thrust Loads Only.



Angular Contact Bearing

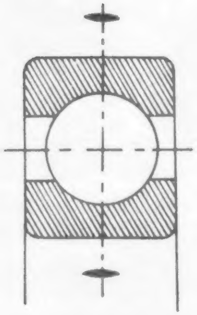
One Shoulder Of Outer Race Removed. Good For Thrust Loads - One Direction

Full Type Bearing

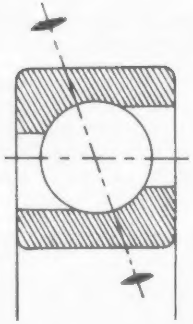


Has A Loading Slot. Holds More Balls, Only For Radial Loads.

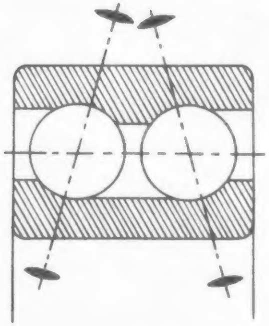
Ball Bearing Designs



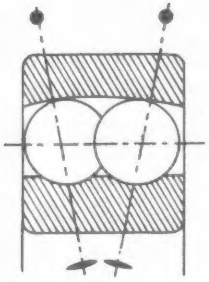
Single Row
Radial



Single Row
Radial-Thrust

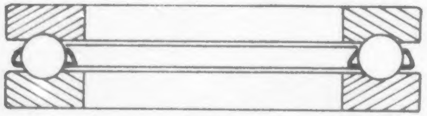


Double Row
Radial-Thrust

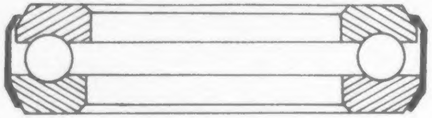


Double Row
Self-Aligning
Radial

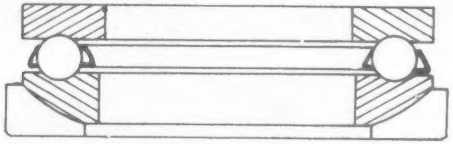
Thrust-Load Ball Bearings



Open Face Ball
Thrust
(Separable)

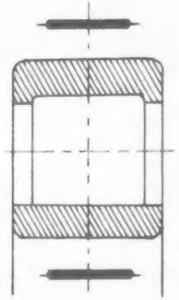


Ball Thrust
Banded Or Shielded

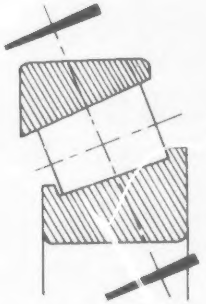


Self-Aligning Ball
Thrust
(Separable)

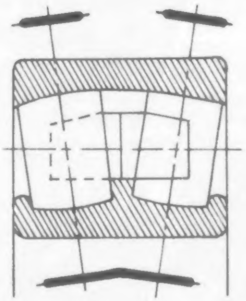
Basic Types Of Roller And Needle Bearings



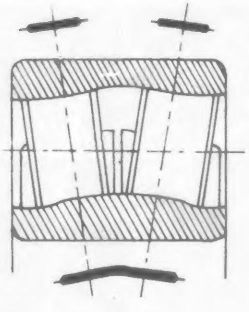
Radial Load,
Straight Roller



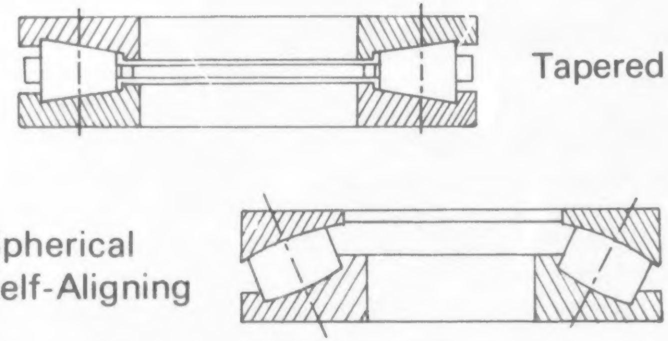
Radial-Thrust,
Tapered Roller



Self-Aligning,
Radial-Thrust
Spherical Rollers



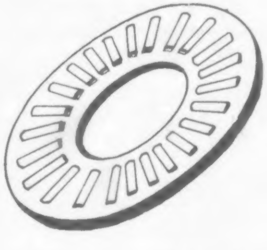
Self-Aligning,
Radial-Thrust
Concave Rollers



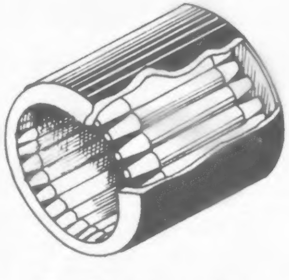
Tapered

Spherical
Self-Aligning

Thrust-Load Roller Bearings

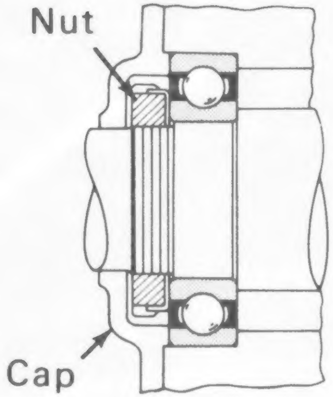


Thrust Load
Bearing

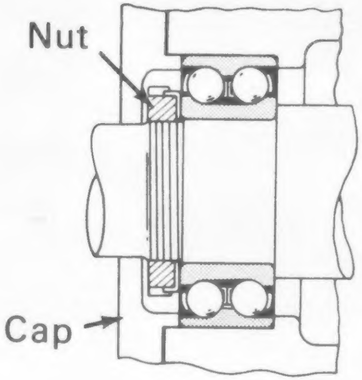


Radial Load
Bearing

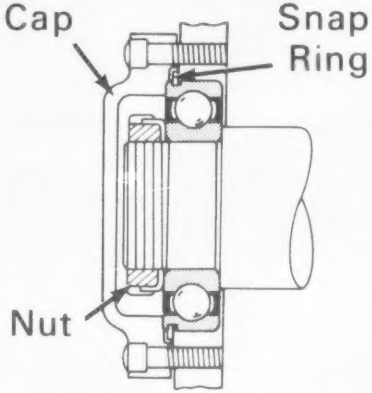
Typical Ball Bearing Mountings



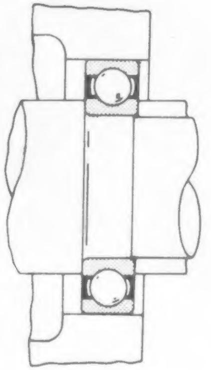
Single Row
Radial



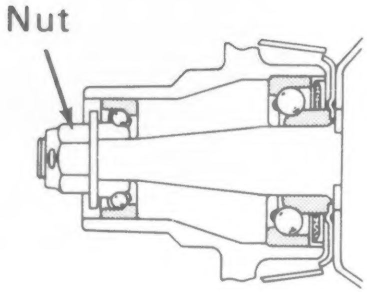
Double Row
Radial-Thrust


Cap
Snap
Ring
Nut

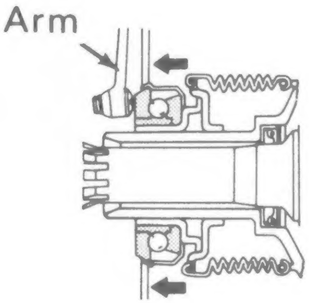
Single Row
Snap Ring



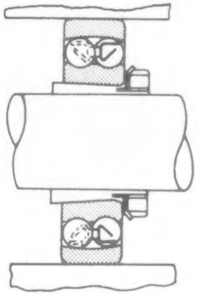
Single Row
"Floated"



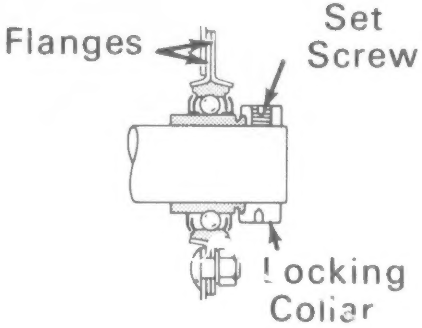
Radial-Thrust



Thrust

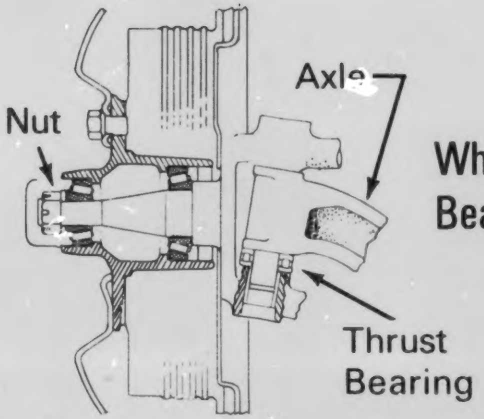


Internally
Self-Aligning

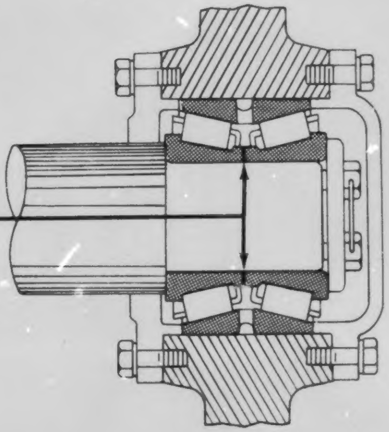

Flanges
Set
Screw
Locking
Collar

Externally
Self-Aligning

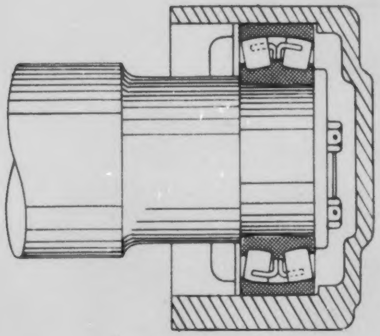
Typical Roller Bearing Mountings


Nut
Axle
Thrust Bearing

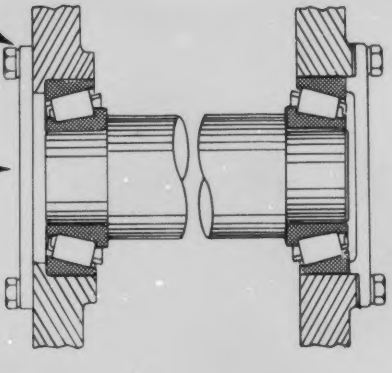
Wheel Bearing


Cones Butted Together

Heavy-Duty Mounting

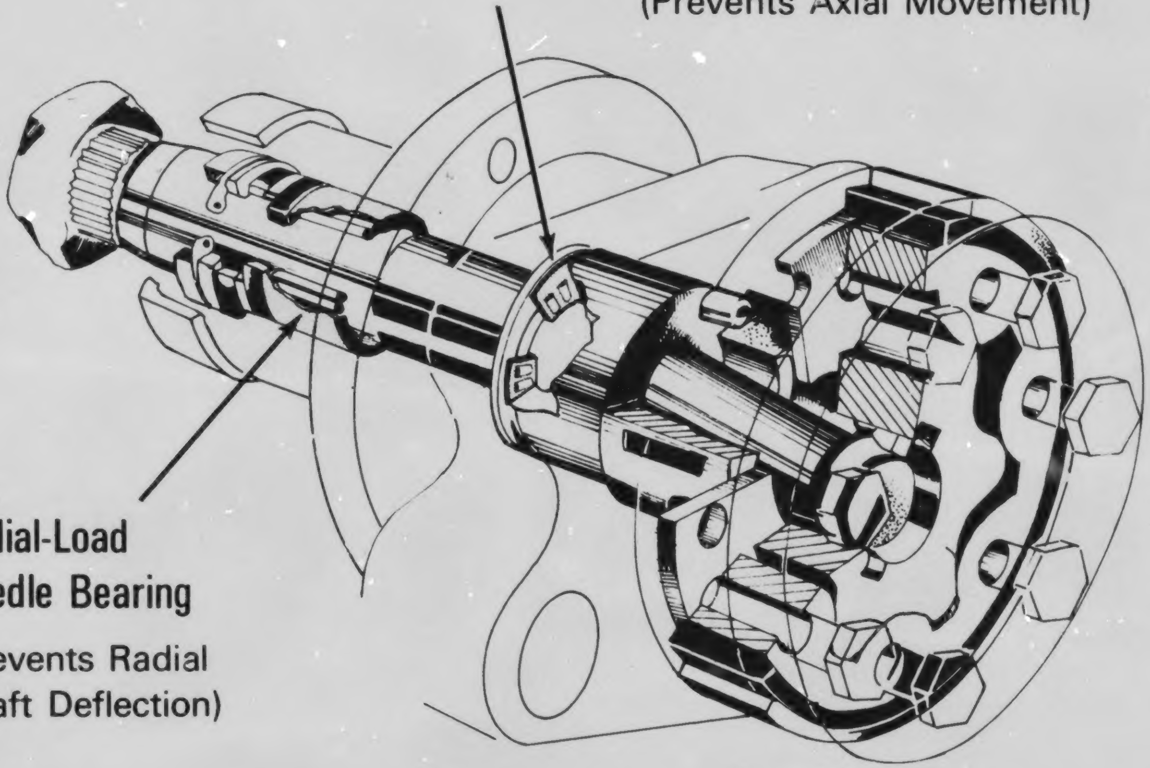


Heavy-Duty Self-Aligning



Transmission Shaft

Typical Needle Bearing Mountings



Thrust-Load Needle Bearing
(Prevents Axial Movement)

Radial-Load Needle Bearing
(Prevents Radial Shaft Deflection)

BEARINGS
UNIT V

JOB SHEET #1--REMOVE AND INSTALL A PLAIN BEARING

I. Tools and materials

  A. Engine

  B. Appropriate service manual

  C. Bearing driver and adapter

  D. Pilot and reamer

  E. Torque wrench

  F. Feeler gauge

  G. Basic hand tool set

  H. Shop towels

  I. Safety glasses

II. Procedure

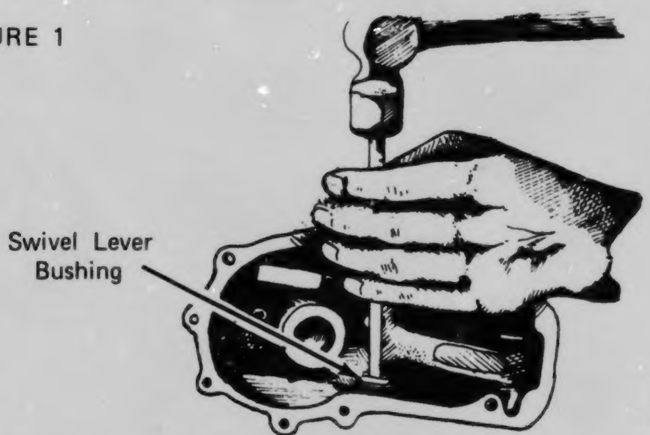
(CAUTION: Follow all shop safety prodecures.)

  A. Replace one piece bearing

    1. Drive old bearing out with driver and adapter (Figure 1)

    (NOTE: Be careful not to damage the bore.)

FIGURE 1



    2. Clean bore and remove any burrs

JOB SHEET #1

3. Drive the bushing straight into the bore (Figure 1)

(NOTE: When possible use a press to assure accuracy. See Figure 2.)

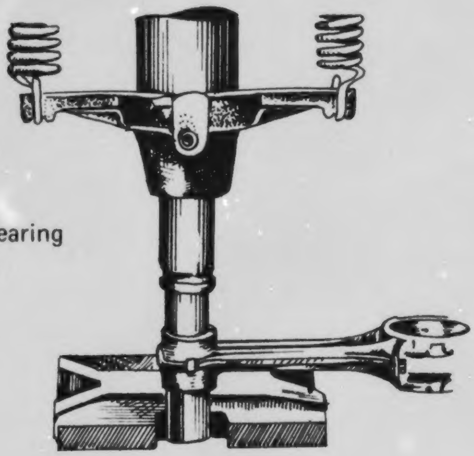


FIGURE 2

Installation Of Bearing With A Press

4. Use a pilot and reamer to size the bearing bore, if necessary (Figure 3)

(NOTE: Never turn a reamer backwards.)

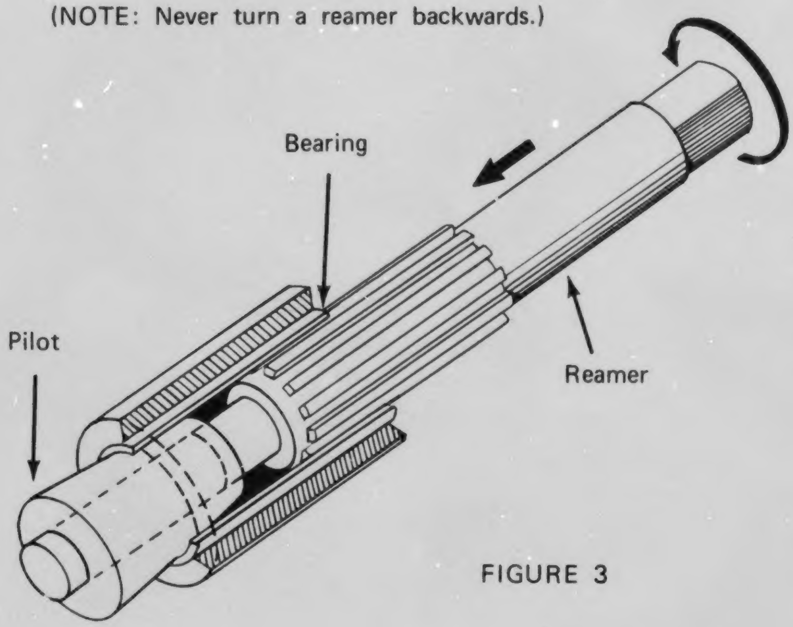


FIGURE 3

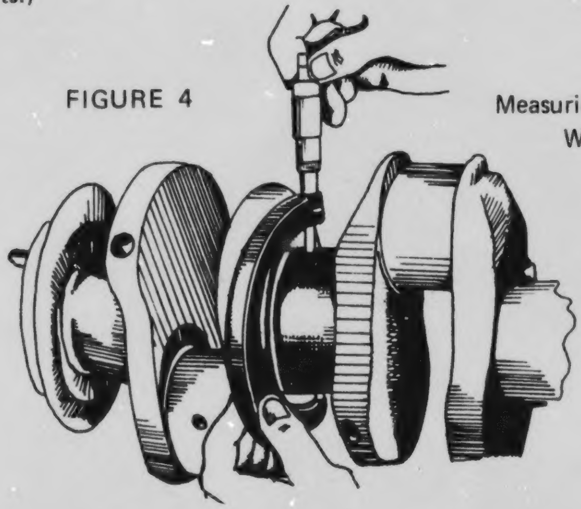
JOB SHEET #1

B. Replace split bearings

1. Measure several places around shaft with micrometer to determine amount of wear (Figure 4)

   (NOTE: See engine manufacturer's technical manual for wear limits.)

FIGURE 4

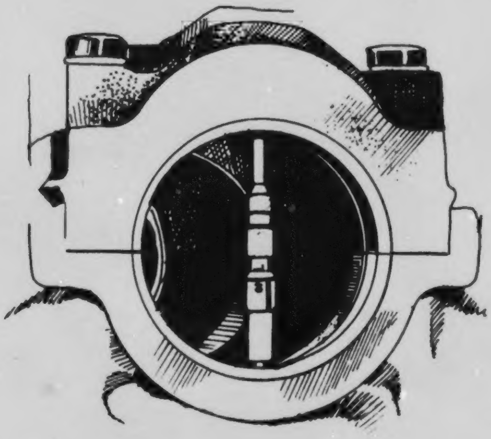


Measuring Shaft Wear

2. Install bearings and tighten to specified torque

3. Use an inside micrometer to measure the inside diameter of bearing (Figure 5)

FIGURE 5



Measuring Bearing Clearance

4. Compare the reading with the outside diameter of the shaft

JOB SHEET #1

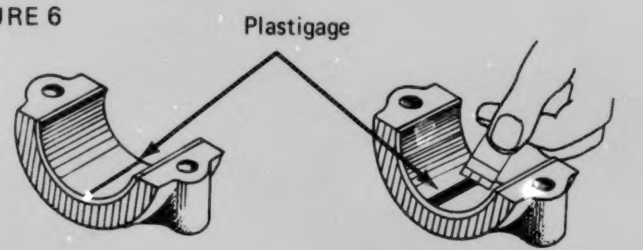
5. Determine the clearance by subtracting the shaft diameter from the bearing inside diameter

   (NOTE: Refer to engine manufacturer's specifications to determine the correct clearance.)

6. Another method of measuring bearing clearance is by using a plastigage (Figure 6)

   (NOTE: This is a plastic thread which "crushes" to the exact clearance when the bearing cap is fully tightened. While this method will give the bearing clearance, it will not tell you whether the wear is on the bearing or on the shaft. Crankshaft must be supported when checking main bearing clearance.)

FIGURE 6



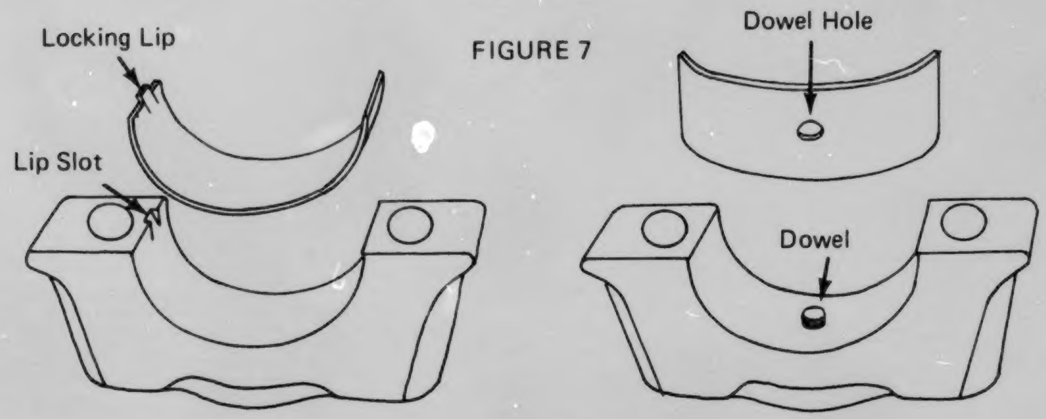
1. Plastigage In Place Before Bearing Cap Is Torqued

2. Plastigage After Bearing Cap Is Removed

7. Install undersize bearings if too much wear has occurred

   (NOTE: When installing the bearing, be careful that it does not cover any oil holes and that the locking devices are in correct relationship. See Figure 7.)

FIGURE 7

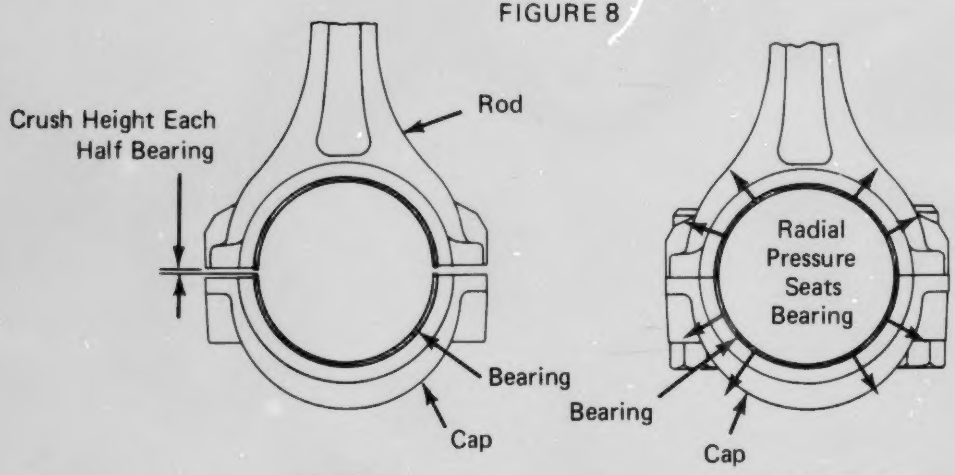


JOB SHEET #1

8. Determine the correct amount of bearing "crush"

   a. Force the insert to seat solidly in bearing seat (Figure 8)

FIGURE 8


Crush Height Each Half Bearing
Rod
Bearing
Cap
Radial Pressure Seats Bearing
Bearing
Cap

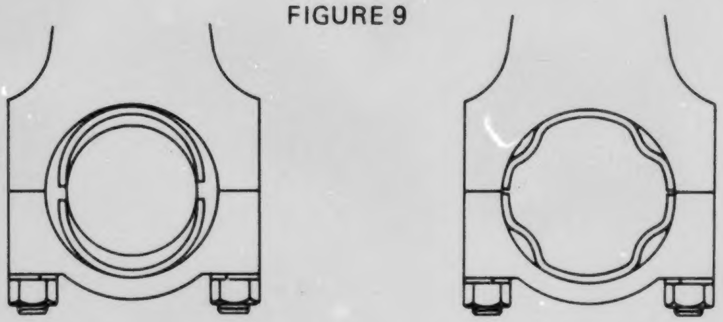
LOOSE

TIGHTENED

   b. Insure that the bearing remains round

   (NOTE: If not tightly held on the edge, it might distort as illustrated in exaggerated form. See Figure 9.)

FIGURE 9



Lack Of Crush
Edges Of Bearing Curl In Toward Shaft

Too Much Crush
Bearing Buckles When Cap Tightened

EFFECTS OF IMPROPER CRUSH

BEARINGS
UNIT V

JOB SHEET #2--REMOVE AND INSTALL AN ANTI-FRICTION BEARING

I. Tools and materials

- A. Engine
- B. Appropriate service manual
- C. Pullers
- D. Press
- E. Vise
- F. Support blocks
- G. Basic tool set
- H. Shop towels
- I. Safety glasses

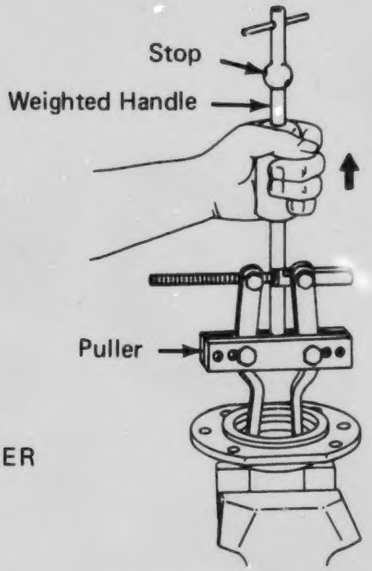
II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Remove bearing using pullers

1. Clean bearing housing and shaft
2. Study bearing mounting and determine how it can be removed using a, b, or c bearing pullers below
   - a. Using a slide hammer puller, slide the hammer against the stop and force bearing from housing (Figure 1)

FIGURE 1

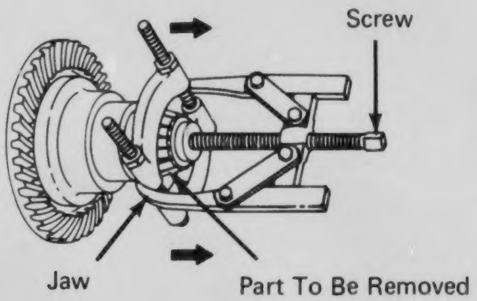


SLIDE-HAMMER
INTERNAL PULLER

JOB SHEET #2

b. Using a screw type puller, pull bearing from the shaft by force of screw turning (Figure 2)

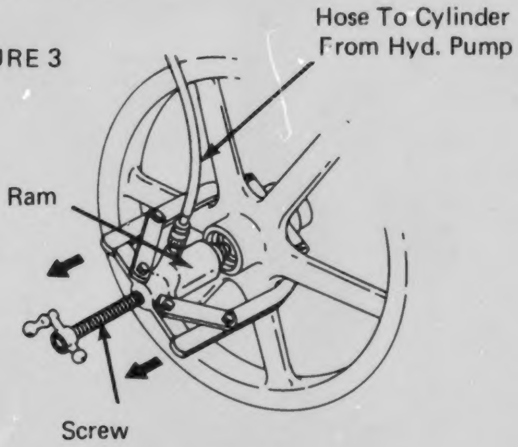
FIGURE 2


Screw
Jaw
Part To Be Removed

EXTERNAL SCREW-TYPE PULLER

c. Using a hydraulic powered puller, pull bearing from shaft by force (Figure 3)

FIGURE 3


Hose To Cylinder From Hyd. Pump
Ram
Screw

HYDRAULICALLY-POWERED PULLER

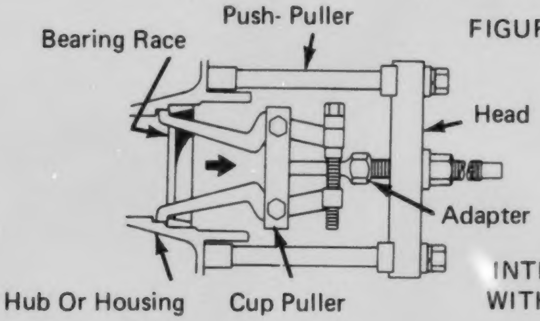
3. Make the correct puller application using a, b, or c below

(NOTE: Pullers may be for either internal or external applications, depending on the need. Some pullers can be used for both jobs because they have reversible jaws with both external and internal ends.)

JOB SHEET #2

a. Make puller application using an internal type with push-puller (Figure 4)

FIGURE 4

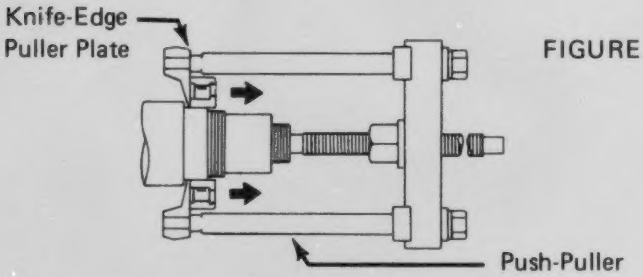

Push- Puller
Bearing Race
Head
Adapter
Hub Or Housing
Cup Puller

INTERNAL PULLER WITH PUSH-PULLER

(NOTE: The push-puller may also be used for installation. The legs of the push-puller support the head while the screw is turned, pulling the bearing cup from the housing.)

b. Make puller application using a knife-edge puller plate with push puller (Figure 5)

FIGURE 5


Knife-Edge
Puller Plate
Push-Puller

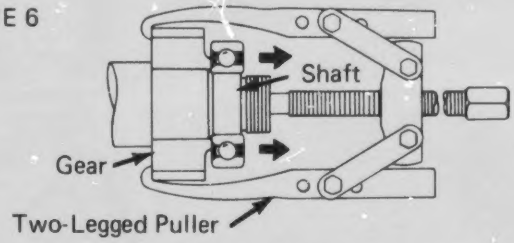
KNIFE-EDGE PULLER PLATE WITH PUSH-PULLER

(NOTE: A knife-edge puller plate is available to remove bearings where other pullers would damage the bearing. This plate is shown (Figure 5) removing a bearing from a shouldered shaft. If the regular external-type puller were used to remove this bearing, the force exerted on the outer race would damage the bearing. Notice that the knife-edge plate is used with a push-puller; the external screw type puller can also be used with the knife-edge plate.)

JOB SHEET #2

c. Make puller application using an external screw type puller (Figure 6)

FIGURE 6


Shaft
Gear
Two-Legged Puller

EXTERNAL SCREW TYPE PULLER

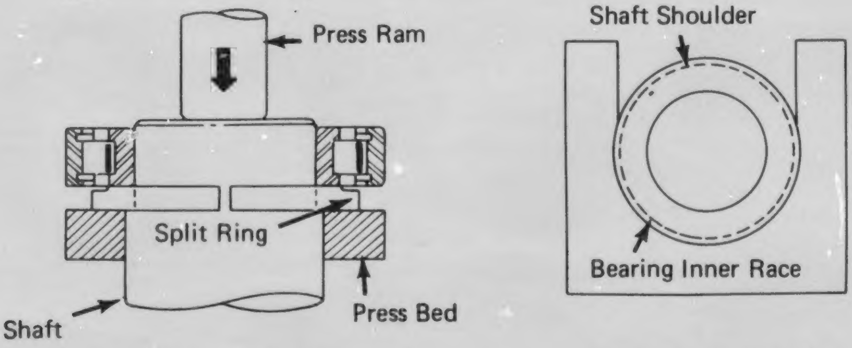
(NOTE: The external screw type puller can be used to remove bearings provided there is some solid object which allows the jaws of the puller to force the bearing off.)

4. Force the bearing from the shaft

B. Remove bearing using a press (Figure 7)

1. Support inner race with split rings or U-plates as available (Figure 7)

FIGURE 7


Press Ram
Split Ring
Shaft
Press Bed
Shaft Shoulder
Bearing Inner Race

SPLIT RING SUPPORT

U-PLATE SUPPORT

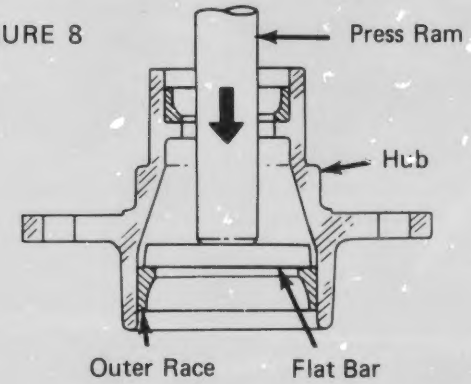
2. Press bearing from shaft

JOB SHEET #2

3. Press bearing cup from housing using a flat bar which transmits ram pressure (Figure 8)

   (NOTE: Housing must be open from opposite side.)

FIGURE 8


Press Ram
Hub
Outer Race
Flat Bar

BEARING CUP REMOVAL

4. Press outer race from housing using a tube slightly smaller than the outer race (Figure 9)

FIGURE 9

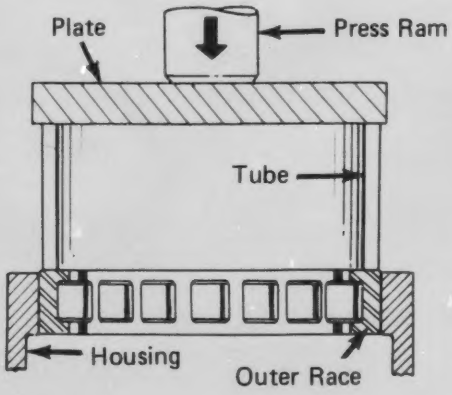


Plate
Press Ram
Tube
Housing
Outer Race

JOB SHEET #2

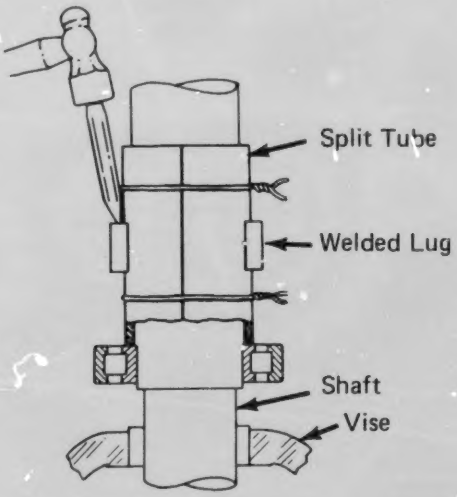
C. Remove bearing with a hammer and driver using either method below

1. Method #1

   a. Place tube over shaft to drive bearing from the shaft (Figure 10)

   (NOTE: If shaft has obstructions, tube may be split and tied.)

FIGURE 10


Split Tube
Welded Lug
Shaft
Vise

   b. Strike the welded lug with hammer and punch

2. Method #2

   a. Use support blocks, split rings, or a U-plate to support inner race of the bearing (Figure 11)

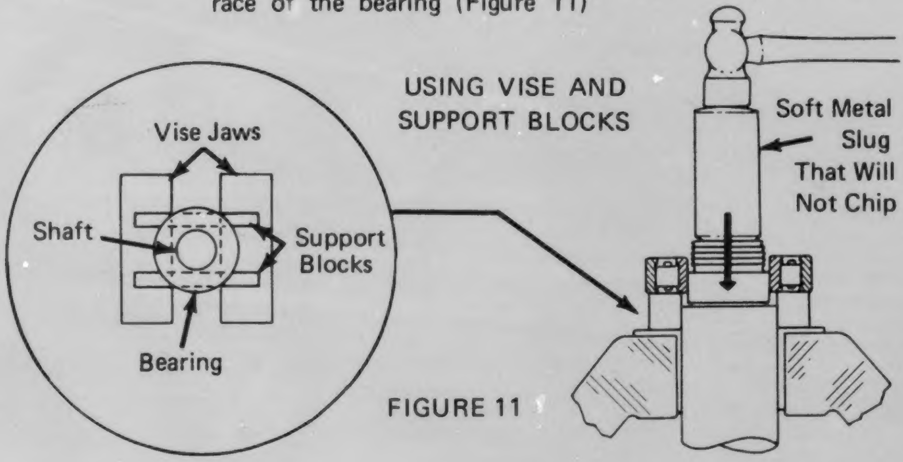

USING VISE AND SUPPORT BLOCKS
Vise Jaws
Shaft
Support Blocks
Bearing
Soft Metal Slug That Will Not Chip

FIGURE 11

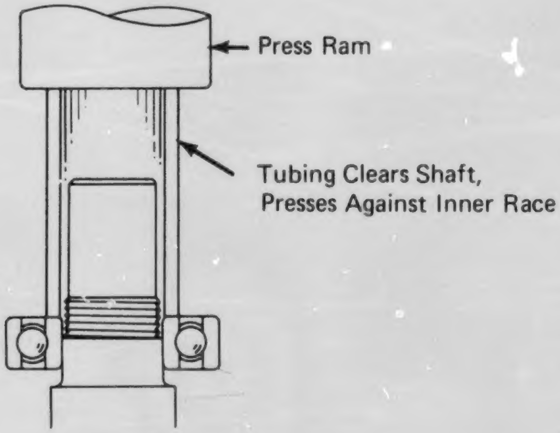
JOB SHEET #2

b. Drive the shaft from the bearing with a soft plug or driver

D. Install bearings using appropriate method below

1. Press inner face on shaft by using press method (Figure 12)

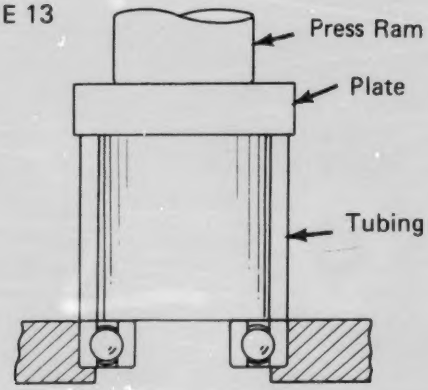
FIGURE 12


Press Ram
Tubing Clears Shaft, Presses Against Inner Race

(NOTE: No pressure is exerted on outer race.)

2. Press outer race in housing by using press method (Figure 13)

FIGURE 13


Press Ram
Plate
Tubing

(NOTE: No pressure is exerted on inner race.)

JOB SHEET #2

3. Drive inner race on shaft with hammer (Figure 14)

FIGURE 14

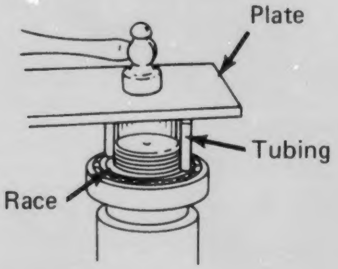


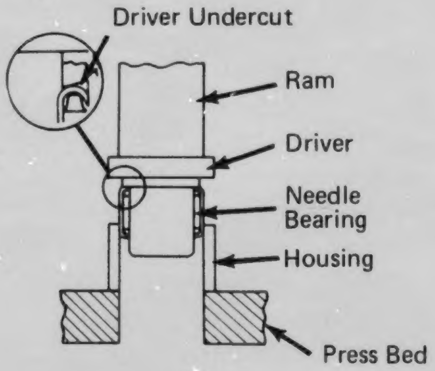
Plate
Tubing
Inner Race

DRIVING INNER RACE ON SHAFT

(NOTE: No pressure is exerted on outer race.)

4. Press needle bearing into housing with press (Figure 15)

FIGURE 15


Driver Undercut
Ram
Driver
Needle Bearing
Housing
Press Bed

(NOTE: Use special undercut driver to transmit driving force to outer shell, preventing bearing shell from buckling.)

BEARINGS
UNIT V

JOB SHEET #3--CHECK PRELOAD BEARING SETTING, SPRING SCALE METHOD

I. Tools and materials

- A. Engine
- B. Appropriate service manual
- C. Spring scale
- D. String or cord
- E. Basic hand tool set
- F. Torque wrench
- G. Safety glasses

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Torque bearing adjusting device to manufacturer's specification
- B. Lubricate bearings, if necessary
- C. Attach string to gear and wind around the outside diameter
- D. Attach spring scale to string (Figure 1)

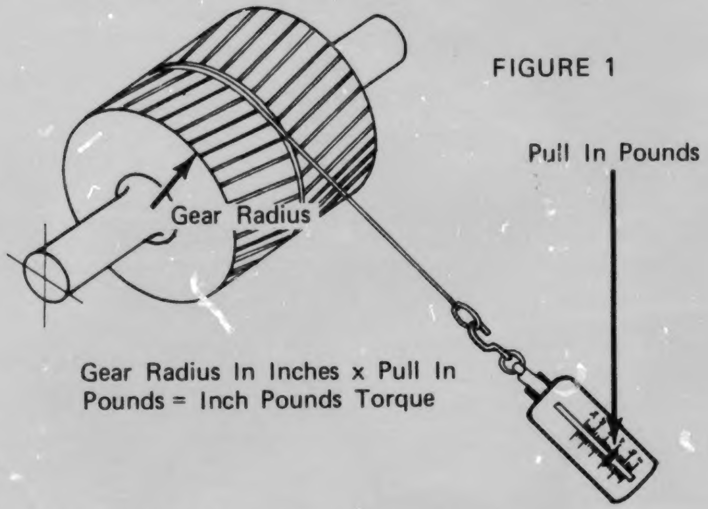


FIGURE 1

Gear Radius In Inches x Pull In Pounds = Inch Pounds Torque

- E. Pull until gear is rotated slowly (Figure 1)

JOB SHEET #3

F. Read the pounds pull necessary to keep gear turning

G. Calculate the rolling torque by multiplying the radius of the gear in inches by the pounds pull on the spring scale (Figure 1)

(NOTE: Compare calculated rolling torque to manufacturer's specifications.)

H. Tighten or loosen the adjusting device to obtain manufacturer's preload bearing setting

BEARINGS
UNIT V

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Resistance to motion between two bodies in contact

_____b. Force is directed sideways or perpendicular to the shaft

_____c. Force is directed endways or horizontal to shaft

_____d. Two hardened steel rings

_____e. Plastic thread which "crushes" to the exact clearance when measuring bearing clearance

_____f. Alloy of lead, tin, antimony, and other metals

_____g. Supporting surface for a wheel or shaft that provides a sliding contact between the mating surfaces

_____h. Supporting surface for a wheel or shaft that provides a rolling contact between mating surfaces

_____i. Each half of the bearing extends one or two thousandths of an inch beyond the bearing seat bore

_____j. Adjustment of anti-friction bearing after being secured in the mounting

1. Axial load
2. Radial load
3. Friction
4. Plastigage
5. Plain bearing
6. Anti-friction bearing
7. Babbit
8. Bearing crush
9. Races
10. Preloading

2. List four functions of bearings.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

3. Name two basic types of bearings.

a. ______________________________

b. ______________________________

4. Distinguish between axial and radial load forces on bearings by placing an "X" next to the description of axial load forces.

______a. Those forces directed endways

______b. Those forces directed sideways or perpendicular to the shaft

5. Match the types of bearings on the right with their advantages and disadvantages.

______a. Advantages
   1. Require little space
   2. Low in cost
   3. Quiet operation
   4. Rigid construction

______b. Advantages
   1. Low friction operation
   2. Can be packed to reduce frequency of lubrication
   3. More versatile, many designs

______c. Disadvantages
   1. High friction operation
   2. Require more frequent lubrication because they cannot be packed

______d. Disadvantages
   1. Require more spaces
   2. Noisier operation
   3. Higher cost
   4. Less rigidity

1. Plain bearings (bushings)

2. Anti-friction bearings

6. Match the illustrations of plain bearings with the correct names.

______a Solid bearing or sleeve

______b. Split bearing, rolled type

______c. Thrust bearing

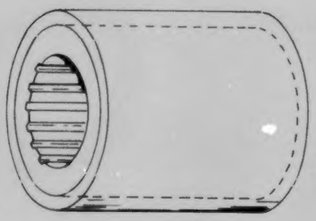
______d. Split bearing with steel back lined with bronze or babbit

______e. Split type constructed of wood, plastic, or rubber

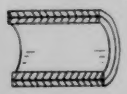
______f. Split bearing used for engine crankshaft

______g. Solid bearing with fluted rubber structure

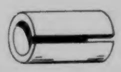
1.



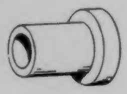
2.



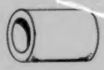
5.



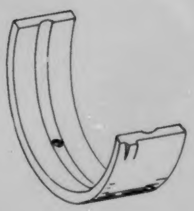
4.



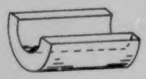
6.



3.



7.



7. List six materials from which bearings may be constructed.

a. ______

b. ______

c. ______

d. ______

e. ______

f. ______

8. List three factors influencing the distribution of lubricant to the bearings.

a. ______________________________

b. ______________________________

c. ______________________________

9. Name four common methods of lubricating bearings.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

10. List five causes of bearing failure in plain bearings.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

11. List four reasons for bearing crush.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

12. Name three types of anti-friction bearings.

a. ______________________________

b. ______________________________

c. ______________________________

13. List three conditions that determine the load carrying capacity of anti-friction bearings.

a. ______________________________

b. ______________________________

c. ______________________________

14. Name four types of ball bearing races.

a. ______

b. ______

c. ______

d. ______

15. List four designs of ball bearings.

a. ______

b. ______

c. ______

d. ______

16. List five types of roller bearings.

a. ______

b. ______

c. ______

d. ______

e. ______

17. Name two types of needle bearings.

a. ______

b. ______

18. Select true statements concerning mountings for anti-friction bearings by placing an "X" in the appropriate blanks.

______a. Shape must not be distorted

______b. Rolling elements must not be bound

______c. Inner and outer races must be aligned

______d. Axis of each bearing must be aligned with the other

______e. Usually mounted with both races pressed fit

______f. Seals are used to retain bearings

19. Select bearing maintenance tips by placing an "X" in the appropriate blanks.

_____a. Work with clean, approved tools, in clean surroundings

_____b. Use clean solvents and flushing oils

_____c. Install new bearings as they come from the package, without washing, if they are received in a sealed container

_____d. Use wooden mallets or work on a soft wood bench

_____e. Lay bearings out on a clean surface

_____f. Handle bearings with dirty or moist hands

_____g. Keep bearings wrapped in oil-proof paper when not in use

_____h. Wipe bearings, if necessary, only with clean, lint-free rags

_____i. Expose bearings to moisture and dirt

_____j. Use the same container for both cleaning and final rinse of used bearings

_____k. Keep lubricants clean when applying them, and cover the containers when not in use

20. Demonstrate the ability to:

a. Remove and install a plain bearing.

b. Remove and install an anti-friction bearing.

c. Check preload bearing setting, spring scale method.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BEARINGS
UNIT V

ANSWERS TO TEST

1. a. 3
   b. 2
   c. 1
   d. 9
   e. 4
   f. 7
   g. 5
   h. 6
   i. 8
   j. 10

2. a. Support the moving part
   b. Reduce friction
   c. Reduce wear
   d. Provide a replaceable wear surface

3. a. Plain bearings
   b. Anti-friction bearings

4. a.

5. a. 1
   b. 2
   c. 1
   d. 2

6. a. 6
   b. 5
   c. 4
   d. 2
   e. 7
   f. 3
   g. 1

7. Any six of the following:

   a. Wood
   b. Cast iron
   c. Soft steel
   d. Hard steel
   e. Copper, brass, and bronze
   f. Copper, lead
   g. Babbit
   h. Aluminum
   i. Plastic
   j. Rubber

8. a. Oil grooves
   b. Bearing clearance
   c. Bearing surface compatibility

9. Any four of the following:
    a. Oil can
    b. Grease gun
    c. Central grease system
    d. Oil bath splash
    e. Pressure feed system

10. Any five of the following:
    a. Dirt
    b. Lack of lubrication
    c. Improper assembly
    d. Misalignment
    e. Overloading
    f. Corrosion

11. a. Greater heat dissipation
    b. Insert is forced to seat solidly
    c. Insures that the bearings remain round
    d. Avoids any possible movement of the bearing in the seat

12. a. Ball
    b. Roller
    c. Needle

13. a. Size of bearing
    b. Number of rolling elements
    c. Type of race

14. a. Conrad
    b. Full type
    c. Split race
    d. Angular contact

15. a. Radial load
    b. Radial and thrust load
    c. Self-aligning, radial load
    d. Thrust load

16. a. Radial load, straight roller
    b. Radial and thrust load, tapered roller
    c. Self-aligning, radial and thrust load, spherical roller
    d. Self-aligning, radial and thrust load, concave roller
    e. Thrust load

17. a. Radial load
    b. Thrust load

18. a, b, c, d

19. a, b, c, e, g, h, k

20. Performance skills evaluated to the satisfaction of the instructor

SEALS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to list three uses of seals and name places where dynamic and static seals are used. The student should also be able to match the names of the dynamic seals to their functions and install a radial lip type seal. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with seals with the correct definitions.
2. List three uses of seals.
3. Name two basic types of seals and their uses.
4. Name three places where dynamic seals are used.
5. Name three places where static seals are used.
6. Match the names of the dynamic seals with their functions.
7. List four types of static seals.
8. Name three categories of sealants.
9. Demonstrate the ability to install a radial lip type seal.

SEALS
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Display several types of dynamic and static seals including O-rings, gaskets and diaphragms.

VIII. Have students make a list of where different seals are used.

IX. Have students identify where the lip faces on different types of seals.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1–Basic Types of Seals
    2. TM 2–Dynamic Seals
    3. TM 3–Dynamic Seals (Continued)
    4. TM 4–Dynamic Seals (Continued)
    5. TM 5–Dynamic Seals (Continued)
    6. TM 6–Dynamic Seals (Continued)

7. TM 7--Dynamic Seals (Continued)
8. TM 8--Dynamic Seals (Continued)
9. TM 9--Dynamic Seals (Continued)
10. TM 10--Dynamic Seals (Continued)
11. TM 11--Dynamic Seals (Continued)
12. TM 12--Dynamic Seals (Continued)
13. TM 13--Static Seals
14. TM 14--Static Seals (Continued)
15. TM 15--Static Seals (Continued)

D. Job Sheet #1--Install a Radial Lip Type Seal

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Bearings and Seals*. 3rd ed. Moline, Illinois: Deere and Company, 1980.

B. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc. 1982.

SEALS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

   A. Dynamic--Moving; relating to force

   B. Static--Without motion; still or fixed

   C. Sealant--Similar to gaskets except applied as a liquid or paste

   D. Static seal--Device which maintains a barrier against the transfer of fluids across two mating surfaces which do not move relative to each other

   E. Gasket--Type of static seal

II. Uses of seals

   A. To keep in fluids

   B. To keep out dirt

   C. To hold pressures or vacuums

III. Basic types of seals and their uses (Transparency 1)

   A. Dynamic--To seal moving parts

   B. Static--To seal fixed parts

IV. Places where dynamic seals are used

   A. Shafts and rods

   B. Compression packings

   C. Piston rings

V. Places where static seals are used

   A. As gaskets

   B. O-rings

   C. Packings

INFORMATION SHEET

VI. Dynamic seals and their functions (Transparencies 2,3,4,5,6,7,8,9,10,11, and 12)

A. Radial lip seals--Used on systems which have moving shafts

(NOTE: Lip seals may be bonded or assembled and are classified by lip types: single lip, double lip, and dual lip.)

B. Exclusion seals--Used to prevent entry of foreign material into the moving parts of machinery

(NOTE: Exclusion seals are classified into four general groups: wipers, scrapers, axial seals, and boots.)

C. Clearance seals--Limit leakage by closely controlling the annular clearance between a rotating or reciprocating shaft and stationary bushing

(NOTE: Clearance seals are classified as labyrinth seals or bushings (rings) and some leakage is permitted.)

D. Ring seals--Depend on surface contact between the seal and the moving part and the seal and the stationary part

(NOTE: Ring seals are split-ring type for reciprocating parts and circumferential for rotary parts.)

E. Face seals--Form a running seal between flat, precision finished surfaces

(NOTE: All face seals have a rotating seal ring, stationary seal ring, spring loaded devices, and static seals.)

F. Compression packings--Create a seal when squeezed between the throat of a stuffing box and its gland

(NOTE: Three classes of packings are fabric, metallic, and plastic.)

G. Molded packings--Fluid being sealed supplies the pressure to seal the packings against the wearing surface

(NOTE: The major types are lip and squeeze. Lip type packings include flange, cup, U-cup, U-ring, and V-ring packings. Squeeze types include O-rings and related forms, plus felt.)

H. Diaphragm seals--Dividing membrane which spans the gap between a moving and stationary member

(NOTE: Diaphragms are two types, rolling and flat. The rolling are like long travel bellows.)

INFORMATION SHEET

VII. Types of static seals (Transparencies 13 and 14)

  A. Nonmetallic

  B. Metallic

  C. Static O-rings (nonmetallic)

  D. Static O-rings (metallic)

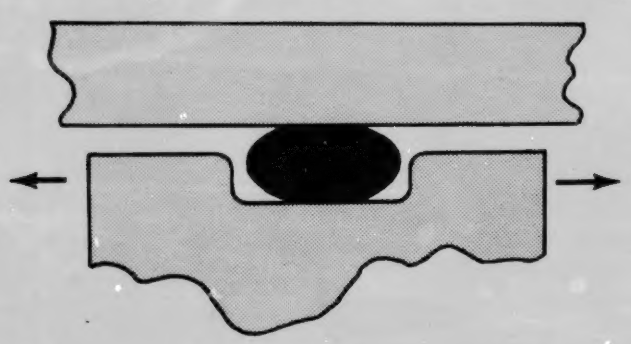
VIII. Categories of sealants (Transparency 15)

  A. Hardening types

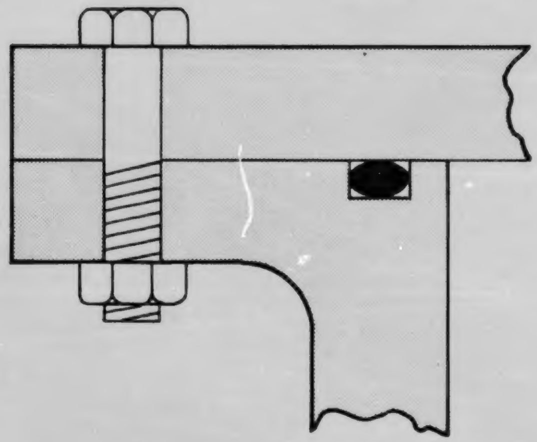
  B. Nonhardening types

  C. Tapes

Basic Types of Seals

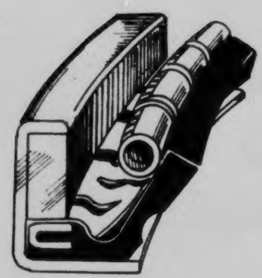


Dynamic Seal

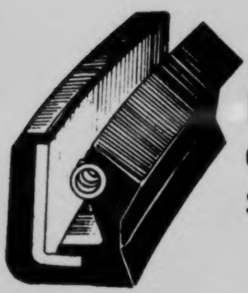


Static Seal

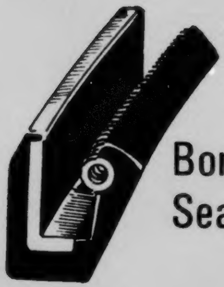
Dynamic Seals



Assembled Seal

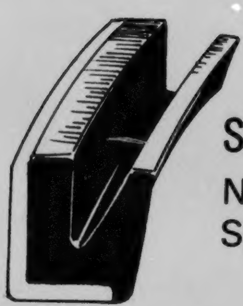


Double Lip Seal
One Lip
Spring-Loaded



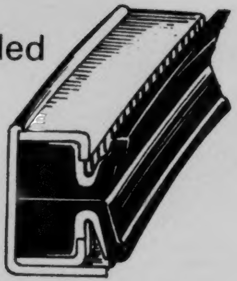
Bonded Seal

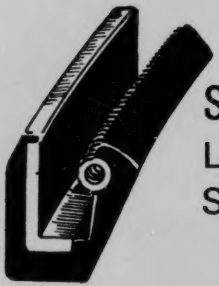
Radial Lip Seals



Single Lip Seal
Not
Spring-Loaded

Dual Lip Seal
Both Lips
Spring-Loaded



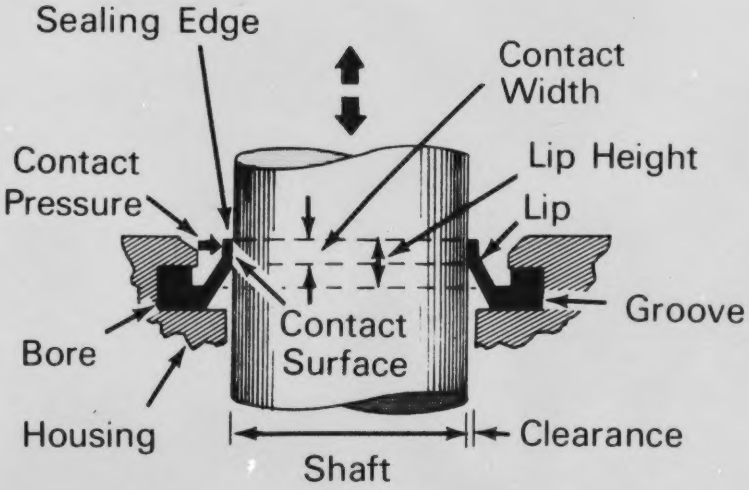


Single Lip Seal
Lip
Spring-Loaded

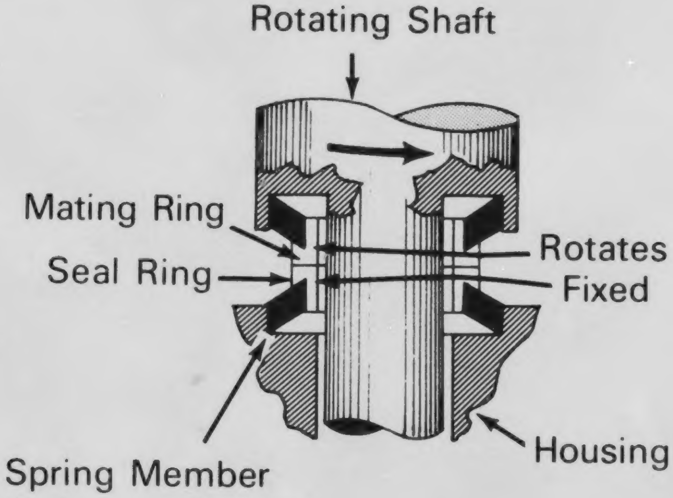
Dynamic Seals

(Continued)

Exclusion Seals


Sealing Edge
Contact Width
Lip Height
Lip
Contact Pressure
Groove
Bore
Contact Surface
Housing
Clearance
Shaft

Radial Exclusion Seal


Rotating Shaft
Mating Ring
Rotates
Seal Ring
Fixed
Spring Member
Housing

Axial Seal

415

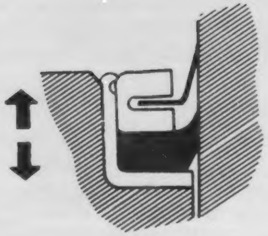
416

TM 3

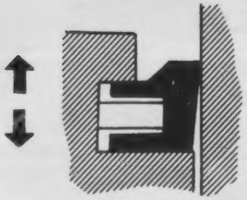
D:F - 183-B

Dynamic Seals

(Continued)



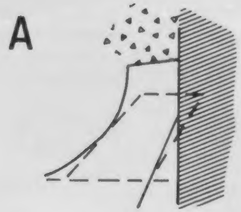
Conical Scraper



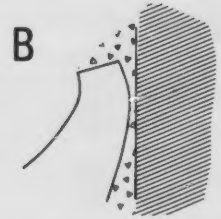
Ring Scraper

Scrapers

Exclusion Seals

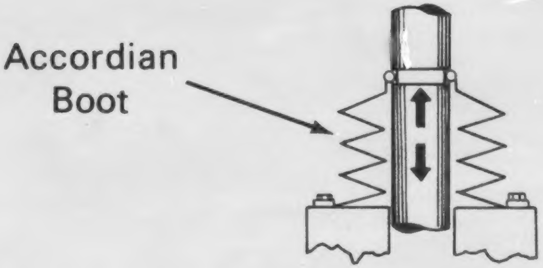


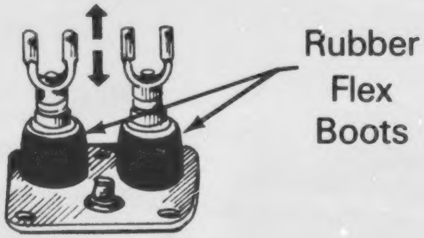
Proper Operation



Lack Of Contact Pressure

Lips Of Wiper Seals


Accordian
Boot

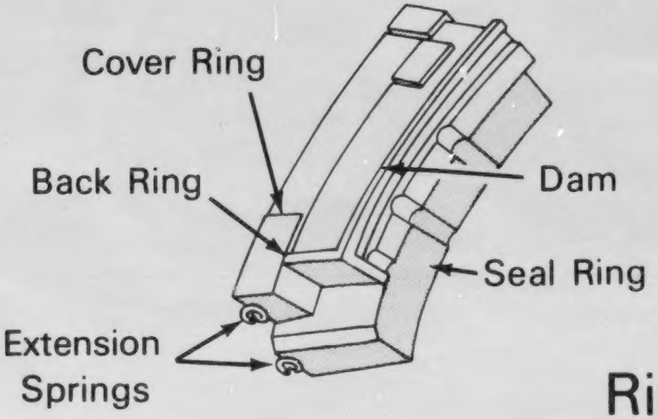

Rubber
Flex
Boots

Boots Which Protect Reciprocating Shafts

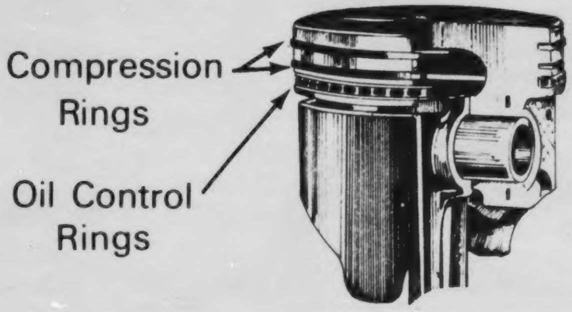
Dynamic Seals

(Continued)

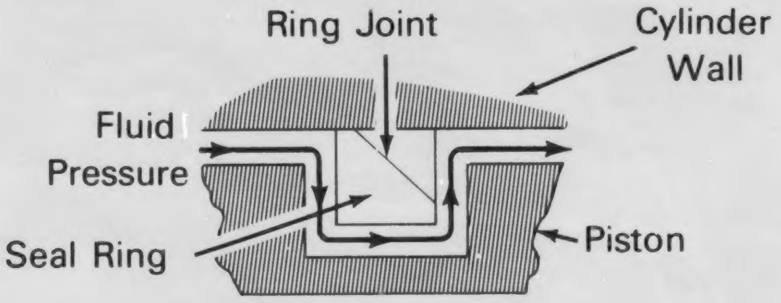
Ring Seals


Cover Ring
Back Ring
Dam
Seal Ring
Extension Springs

Circumferential Seal


Compression Rings
Oil Control Rings

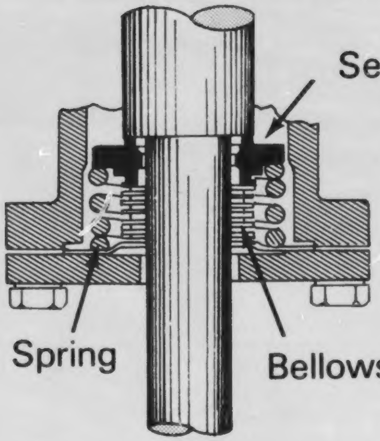
Split-Ring Seals On An Engine Piston


Ring Joint
Cylinder Wall
Fluid Pressure
Seal Ring
Piston

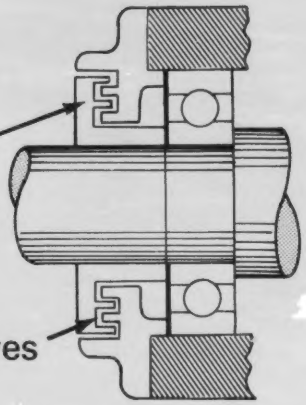
How A Split Ring Seals

Dynamic Seals

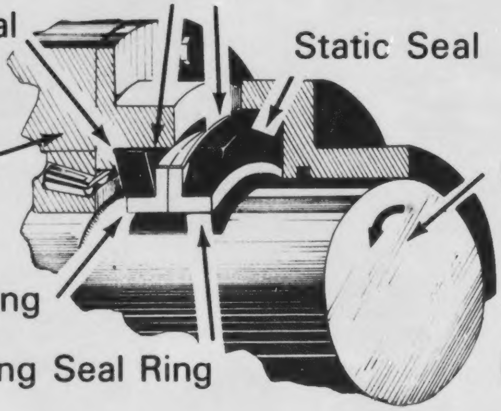
(Continued)


Seal Face
Spring
Bellows

Metal Bellows Seal On Shaft

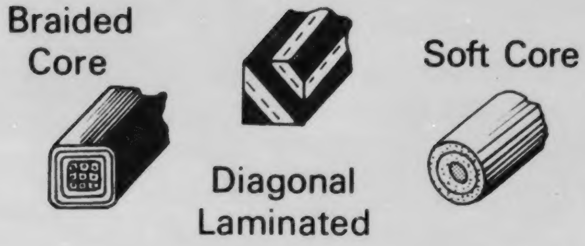

Tongue And Groove Helps Seal Against Contamination
Strips Or Knives

Labyrinth Seal (Clearance Seal)


Spring-Loading Device (Opposed Washers)
Static Seal
Static Seal
Housing (Stationary)
Rotating Shaft
Stationary Seal Ring
Rotating Seal Ring

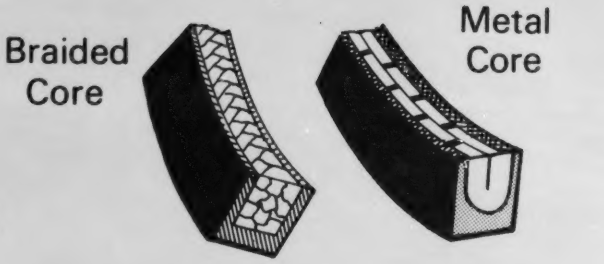
Face Seal (Axial Mechanical Seal)

Dynamic Seals
(Continued)

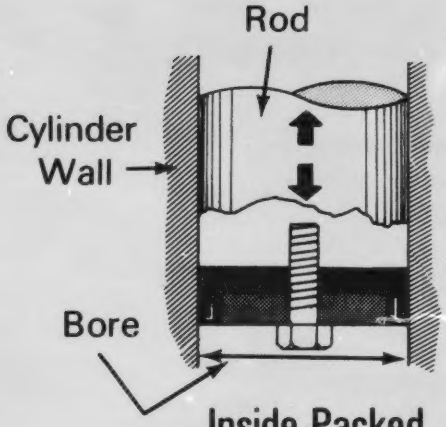

Braided Core
Diagonal Laminated
Soft Core

Fabric Packings

Typical Compression Packings

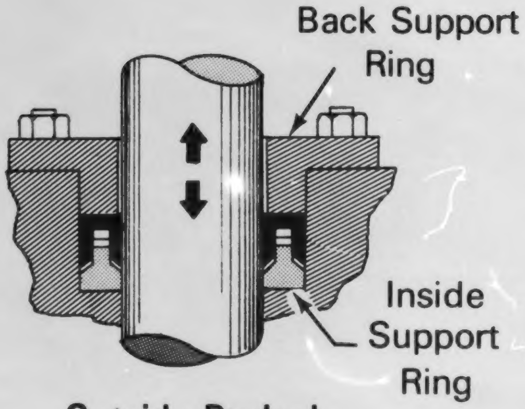

Braided Core
Metal Core

Metallic Packings


Rod
Cylinder Wall
Bore

Inside-Packed

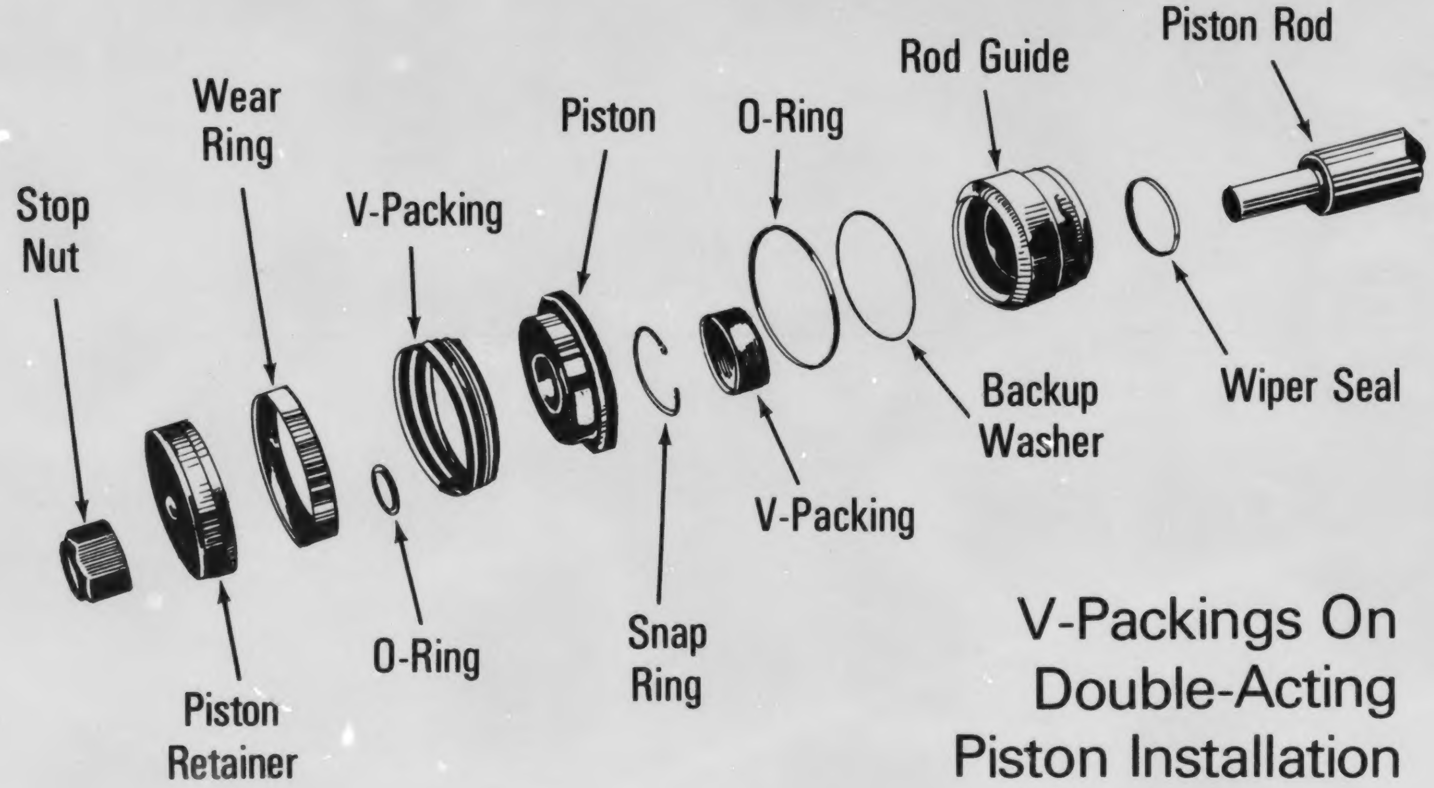
Inside And Outside-Packed Installations


Back Support Ring
Inside Support Ring

Outside-Packed

Dynamic Seals

(Continued)


Piston Rod
Rod Guide
O-Ring
Piston
Wear Ring
V-Packing
Stop Nut
Wiper Seal
Backup Washer
V-Packing
Snap Ring
O-Ring
Piston Retainer

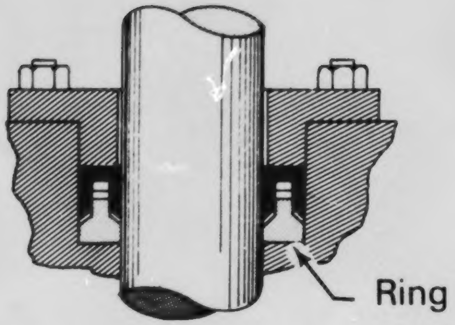
V-Packings On Double-Acting Piston Installation

Dynamic Seals

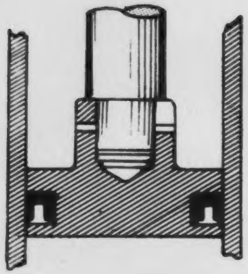
(Continued)

Typical U-Cup Packings

Molded Packings



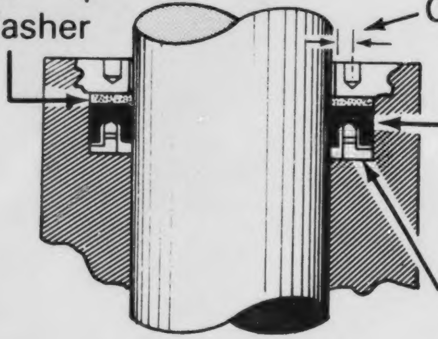
Leather U-Packing Supported By Metal Pedestal Ring Drilled Cross-Wise To Equalize Pressure.



Inside-Packed Installation For A Single-Acting Piston.

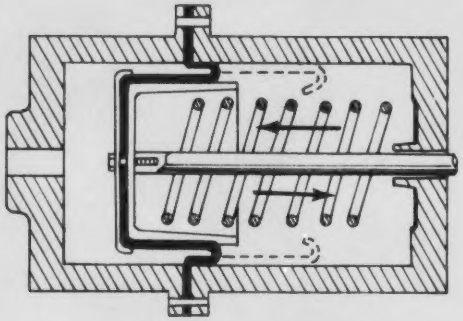
U-Ring Packing (Leather Type Shown)

Outside-Packed Installation With Ring And U-Cup Supported On A Pedestal Ring Drilled Cross-Wise To Equalize Pressure.

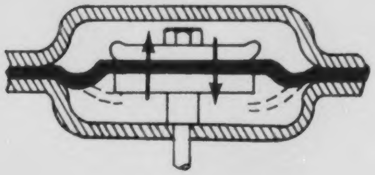

Leather Back-Up Washer
Clearance
U-Cup
Metal Support Ring

Dynamic Seals
(Continued)

Diaphragm Seals

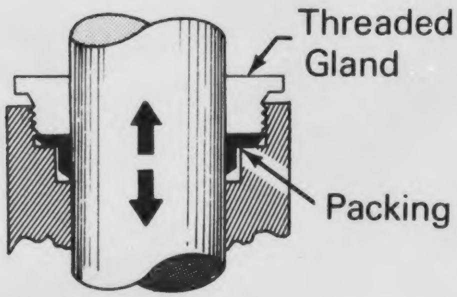


Rolling Diaphragm



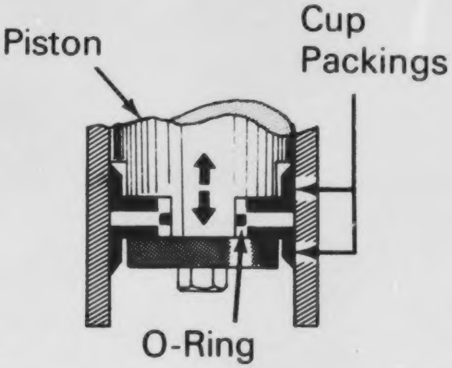
Flat Diaphragm

Molded Packings


Threaded Gland
Packing

Flange Packings

Sleeve Prevents Transfer Of Loads Between Cups

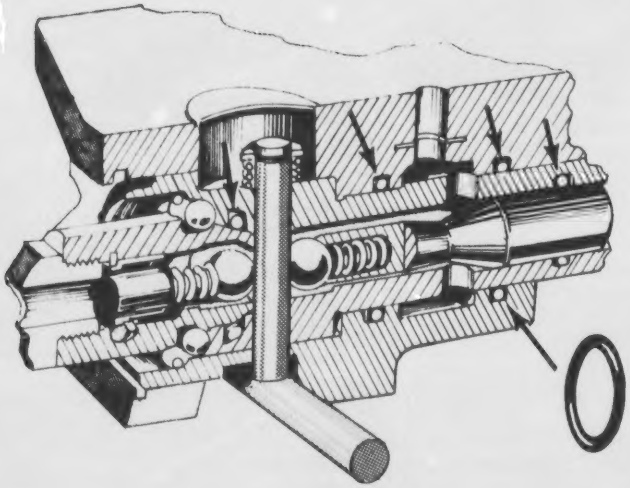

Piston
Cup Packings
O-Ring

Cup Packings For Double-Acting Unit

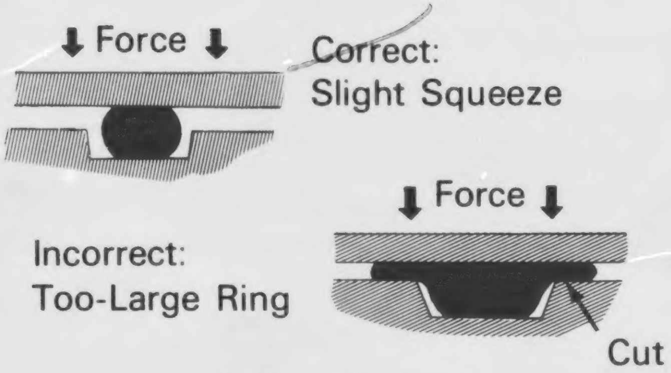
Dynamic Seals

(Continued)

Molded Packings



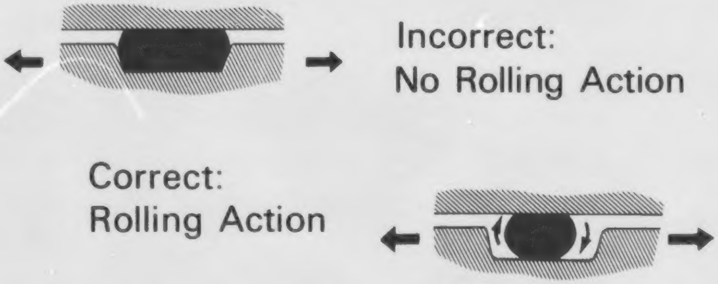
Squeeze-Type Packings
(O-Rings Shown)



Correct:
Slight Squeeze

Incorrect:
Too-Large Ring

O-Ring Squeeze



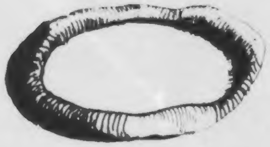
Incorrect:
No Rolling Action

Correct:
Rolling Action

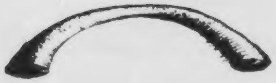
O-Ring Rolling Action

Dynamic Seals

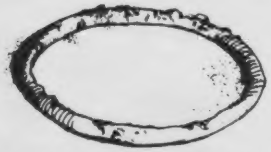
(Continued)



Swollen O-Ring:
Use of Wrong Fluid

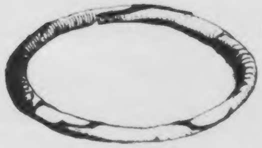


Flattened O-Ring:
Use of Low-Grade Rings

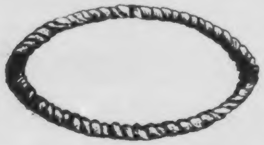


Dirty O-Ring:
Poor Storage or Contaminated System

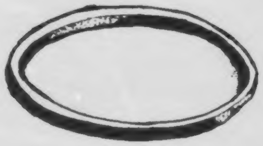
O-Ring Failures



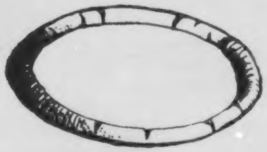
Cut O-Ring:
Shaft Damage or Installed Wrong



Twisted O-Ring:
Installed Wrong

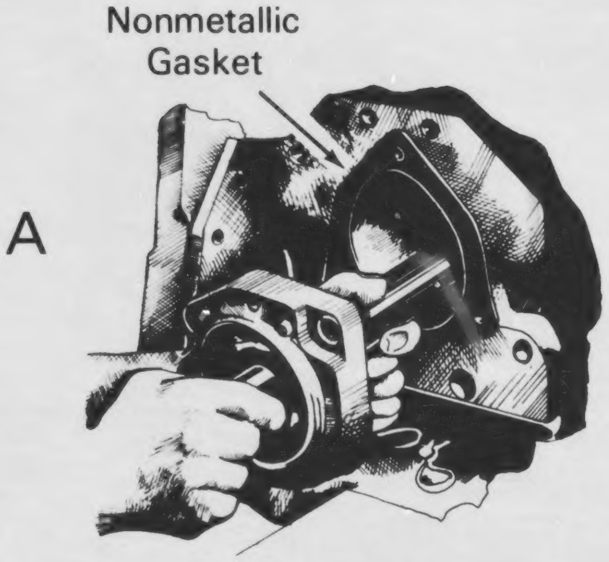


Worn O-Ring:
Lack of Lubrication



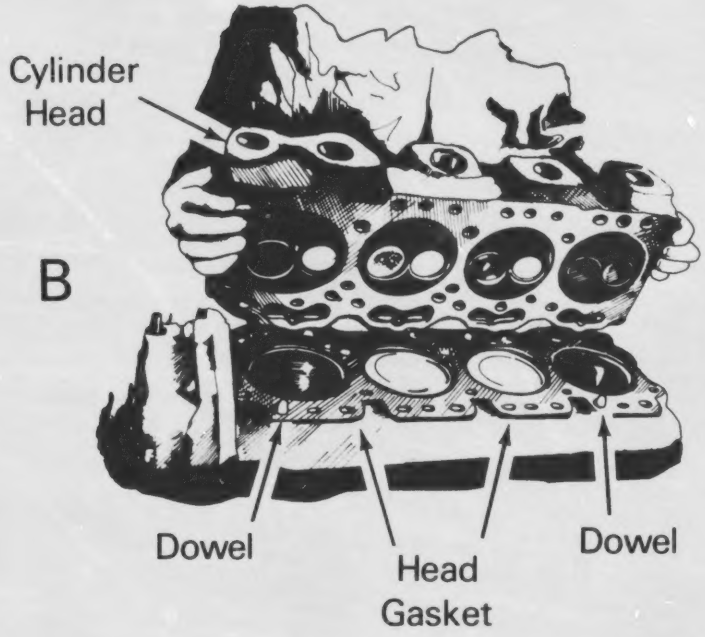
Cracked O-Ring:
Too Much Heat

Static Seals


Nonmetallic
Gasket
A

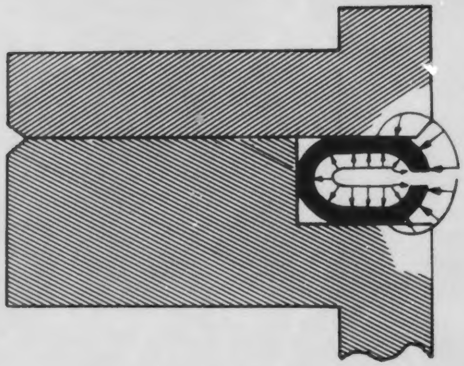
Nonmetallic Gasket
In Low-Pressure Application

Metallic (Combination) Gasket
On Engine Cylinder Head

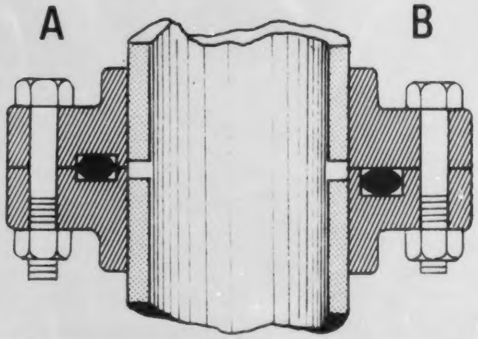

Cylinder
Head
B
Dowel
Head
Gasket
Dowel

Static Seals

(Continued)



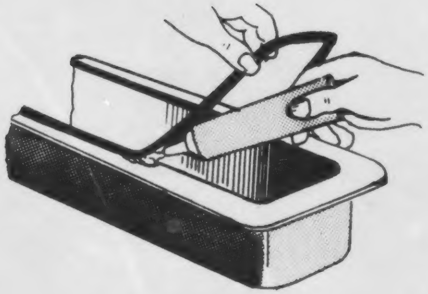
Typical Metallic O-Ring
In Static Use



Nonmetallic Static O-Rings
In Flange Joints
(Two Types Of Rectangular
Grooves Shown)

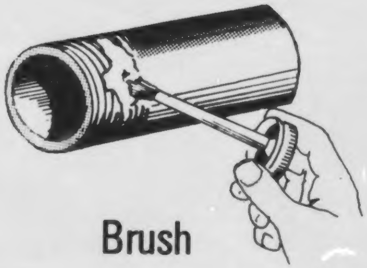
Static Seals

(Continued)

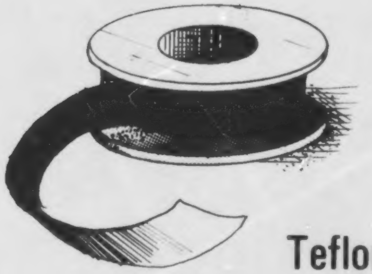


Tube

Sealants
Are "Gaskets"
Which Are Applied In
Liquid Or Paste Form

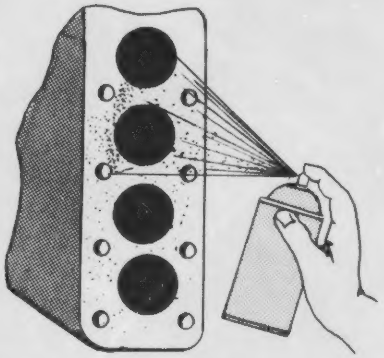


Brush



Teflon Tape

Spray



SEALS
UNIT VI

JOB SHEET #1--INSTALL A RADIAL LIP TYPE SEAL

I. Tools and materials

- A. Seal installation tools recommended in appropriate service manual
- B. Gasket cement
- C. Emery cloth
- D. Basic hand tool assortment
- E. Shop towels (lint free)
- F. Appropriate service manual
- G. Safety glasses

II. Procedure

(CAUTION: Follow all shop safety procedures.)

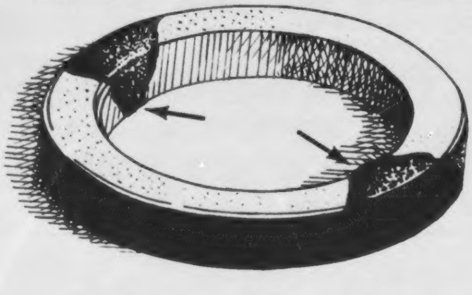
- A. Clean the shaft or bore area and inspect for damage
- B. File or stone any burrs or bad nicks and polish with fine emery cloth to a ground finish
- C. Clean area and remove all metal particles
- D. Lubricate the seal, especially any lips, and the shaft to ease installation, using the system fluid to lubricate the seal and shaft

  (NOTE: On seals with single lips, the lip should normally face in toward the system lubricant. This is usually the garter spring side.)

- E. With metal cased seals, coat the seal's outside diameter with a thin film of gasket cement to prevent bore leakage, and do not allow excess cement to run onto sealing lips (Figure 1)

  (NOTE: Precoated seals do not require cement on the bore fit.)

FIGURE 1



Too Much Sealant On Case
Runs Onto Sealing Lips

JOB SHEET #1

F. Install the seal (Figures 2 and 3)

(NOTE: The use of a factory specified installation tool may be required. This is very important with pressed-in seals. If a seal driving tool is not available, use a circular ring such as an old bearing race that contacts the seal case near the outer diameter, or use a square wooden block. Do not use sharp tools, and never press on the sealing lip, only the outer metal case.)

FIGURE 2

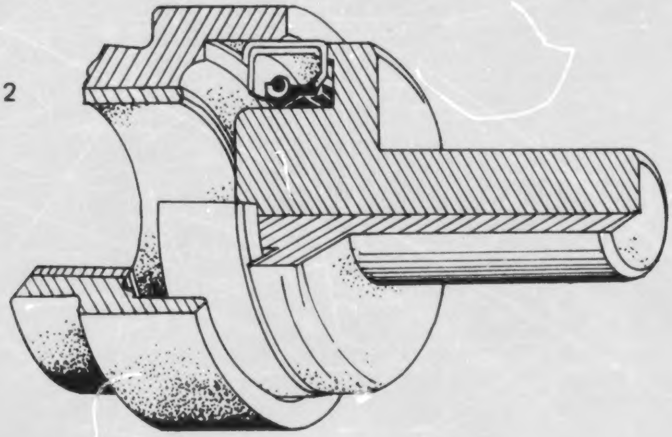
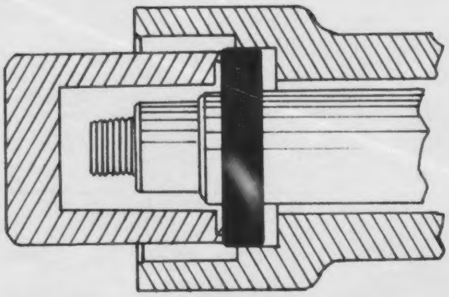


FIGURE 3



JOB SHEET #1

G. Protect the sealing lip when installing the seal over sharp corners of shafts, keyways, or splines (Figures 4 and 5)

(NOTE: Shim stock can also be used to protect seals when installing them over sharp edges such as shaft splines. Place rolled plastic shim stock over the sharp edge, then pull it out after the seal is in place.)

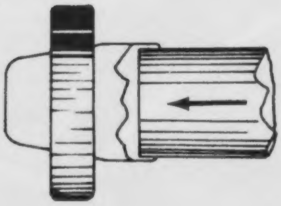


FIGURE 4

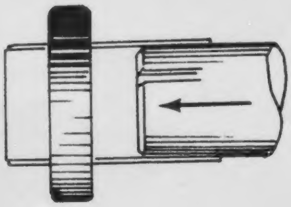


FIGURE 5

H. Drive the seal in evenly to prevent "cocking" of the seal (Figures 6 and 7)

(NOTE: A cocked seal allows oil to leak out and dirt to enter as shown. Be careful not to bend or "dish" the flat metal area of metal cased seals. This causes the lips to be distorted.)

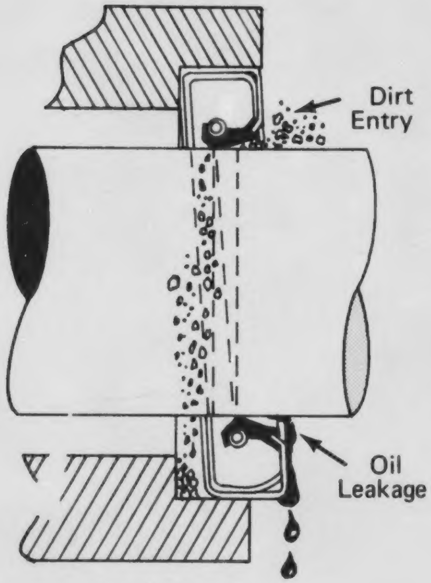

Dirt Entry
Oil Leakage

FIGURE 6

Cocked Seals Allow Dirt To Enter And Oil To Leak Out

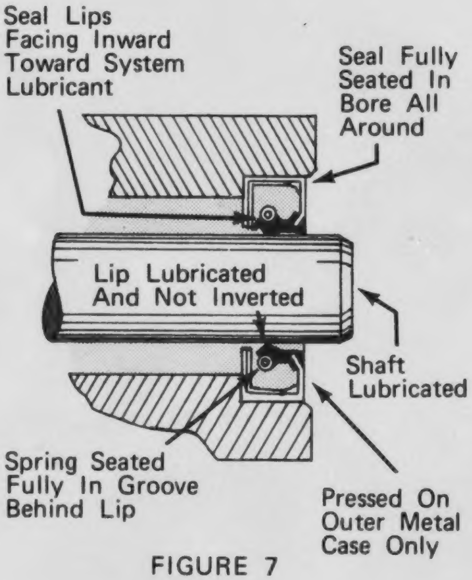

Seal Lips Facing Inward Toward System Lubricant
Seal Fully Seated In Bore All Around
Lip Lubricated And Not Inverted
Shaft Lubricated
Spring Seated Fully In Groove Behind Lip
Pressed On Outer Metal Case Only

FIGURE 7

JOB SHEET #1

I. After assembly, always check the unit by hand for free operation, if possible, before starting up the system

(NOTE: Try to prevent dirt and grit from falling on shafts and being carried into the seal. This material can quickly damage the seal or score the metal surfaces.)

J. Run in new lip type seal (checking)

(NOTE: When a new lip type seal is installed on a clean shaft, a break in period of a few hours is required to seat the seal lip with the shaft surface. During this period, the seal polishes a pattern on the shaft and the shaft in turn seats the lip contact, wearing away the knife-sharp lip contact to a narrow band. During this period, slight seepage may occur. After seating, the seal should perform without any measurable leakage.)

SEALS
UNIT VI

NAME ________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Moving; relating to force

_____b. Without motion; still or fixed

_____c. Similar to gaskets except applied as a liquid or paste

_____d. Device which maintains a barrier against the transfer of fluids across two mating surfaces which do not move relative to each other

_____e. Type of static seal

1. Static seal
2. Static
3. Sealant
4. Gasket
5. Dynamic

2. List three uses of seals.

a. ________________

b. ________________

c. ________________

3. Name two basic types of seals and their uses.

a. ________________

b. ________________

4. Name three places where dynamic seals are used.

a. ________________

b. ________________

c. ________________

5. Name three places where static seals are used.

a. ________________

b. ________________

c. ________________

6. Match the names of the dynamic seals on the right with their functions.

______a. Used on systems which have moving shafts

______b. Used to prevent entry of foreign material into the moving parts of machinery

______c. Limit leakage by closely controlling the annular clearance between a rotating or reciprocating shaft and stationary bushing

______d. Depend on surface contact between the seal and the moving part and the seal and the stationary part

______e. Form a running seal between flat, precision finished surfaces

______f. Create a seal when squeezed between the throat of a stuffing box and its gland

______g. Fluid being sealed supplies the pressure to seal the packings against the wearing surface

______h. Dividing membrane which spans the gap between a moving and stationary member

1. Ring seals
2. Radial lip seals
3. Face seals
4. Molded packings
5. Exclusion seals
6. Clearance seals
7. Diaphragm seals
8. Compression packings

7. List four types of static seals.

a. ____

b. ____

c. ____

d. ____

8. Name three catagories of sealants.

a. ____

b. ____

c. ____

9. Demonstrate the ability to install a radial lip type seal.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

SEALS
UNIT VI

ANSWERS TO TEST

1. a. 5
   b. 2
   c. 3
   d. 1
   e. 4

2. a. To keep in fluids
   b. To keep out dirt
   c. To hold pressures or vacuums

3. a. Dynamic--To seal moving parts
   b. Static--To seal fixed parts

4. a. Shafts and rods
   b. Compression packings
   c. Piston rings

5. a. As gaskets
   b. O-rings
   c. Packings

6. a. 2
   b. 5
   c. 6
   d. 1
   e. 3
   f. 8
   g. 4
   h. 7

7. a. Nonmetallic
   b. Metallic
   c. Static O-rings (nonmetallic)
   d. Static O-rings (metallic)

8. a. Hardening types
   b. Nonhardening types
   c. Tapes

9. Performance skill evaluated to the satisfaction of the instructor

CYLINDER HEAD ASSEMBLY
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to disassemble, inspect, service, and assemble a cylinder head and its containing parts. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with a cylinder head with the correct definitions.
2. Name major parts usually found in a cylinder head assembly.
3. Name three forms of cylinder head castings that may be found on a diesel engine.
4. Identify the primary parts of a valve assembly.
5. List two types of valve rotators.
6. Match valve arrangements with the types of engine heads.
7. List two locations for turbulence chambers in an engine.
8. Identify three forms of engine valves.
9. Demonstrate the ability to:
    a. Remove, inspect, and install a cylinder head.
    b. Disassemble and service a valve train.
    c. Service valve guides.
    d. Service valve seats.
    e. Service valve seat inserts.
    f. Assemble a cylinder head.

CYLINDER HEAD ASSEMBLY
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Have students list the parts in a head assembly.

VIII. Demonstrate different valve angles.

IX. Show various valve designs.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Valve Assembly
      2. TM 2--Valve Rocker Arm Assembly
      3. TM 3--Energy Cell
      4. TM 4--Valve and Fuel Injector
      5. TM 5--Primary Parts of a Valve Assembly
      6. TM 6--Valve Rotators
      7. TM 7--Valve Arrangements and Turbulence Chambers
      8. TM 8--Forms of Engine Valves

D. Job sheets

1. Job Sheet #1--Remove, Inspect, and Install a Cylinder Head
2. Job Sheet #2--Disassemble and Service a Valve Train
3. Job Sheet #3--Service Valve Guides
4. Job Sheet #4--Service Valve Seats
5. Job Sheet #5--Service Valve Seat Inserts
6. Job Sheet #6--Assemble a Cylinder Head

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Engines.* 5th ed. Moline, Illinois: Deere and Company, 1980.

B. *Shop Manual*. Columbus, Indiana: Cummins Engine Company, 1974.

C. Kates, Edgar J. *Diesel and High-Compression Gas Engines*. 3rd ed. Chicago: American Technical Society, 1974.

D. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

CYLINDER HEAD ASSEMBLY
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Service--To clean, inspect, lubricate, and/or adjust

B. Poppet valve--Disk with a stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring (Transparency 1)

C. Valve seat--That part in the head upon which the valve face rests to close the port (Transparency 1)

D. Valve guide--Hole through which the stem of the valve passes (Transparency 1)

(NOTE: Some guides are pressed into place and others are drilled into head metal.)

E. Valve spring--Helical spring used to close the valve (Transparency 1)

F. Valve spring retainers--Hold the valve spring on the valve stem

G. Rocker arm shaft--Serves as a fulcrum for rocker arms (Transparency 2)

H. Rocker arm--Lever that transmits the action of the cam to the stem of the valves (Transparency 2)

I. Rocker arm assembly--Shaft, rocker arm, and cam follower (Transparency 2)

J. Cam follower--Intermediate contact between camshaft and valve stem (Transparency 2)

(NOTE: This is sometimes called a valve lifter.)

K. Energy cell--Special removable combustion chamber for high speed diesel engines (Transparency 3)

L. Turbulence--High velocity swirling of air within the combustion chamber

M. Valve seat angle--Angle between the seat surface and the cylinder head surface, either 30 or 45 degrees

(NOTE: Some manufacturers recommend interference fit of 29 or 44 degrees.)

N. Torque--A twisting effort

INFORMATION SHEET

   O. Torque wrench--Wrench used to draw nuts to a specified tension by measuring the twisting effort in foot-pounds

   P. Foot-pound--Equivalent to raising one pound a distance of one foot

   Q. Fuel injector--Meters and sprays fuel into the combustion chamber (Transparency 4)

   R. Fuel injection nozzle--Injects fuel under high pressure

II. Major parts usually found in a cylinder head assembly (Transparency 4)

   A. Intake valve

   B. Exhaust valve

   C. Rocker arm

   D. Fuel injector or nozzle

   E. Cam followers

   F. Fuel injector tube

   G. Valve guides

   H. Valve seats

III. Forms of cylinder head castings

   A. Single

   (NOTE: This covers one cylinder.)

   B. Multiple

   (NOTE: This covers two or more cylinders.)

   C. One piece

   (NOTE: This covers all cylinders.)

IV. Primary parts of a valve assembly (Transparency 5)

   A. Split collar retainers (valve keepers)

   B. Valve spring cup

   C. Valve spring

   D. Valve

INFORMATION SHEET

V. Types of valve rotators (Transparency 6)

   A. Release type

   B. Positive type

VI. Typical valve arrangements (Transparency 7)

   A. I-Head--Both valves above cylinder

   B. H-Head--Both valves above angled cylinders (V-block)

   C. F-Head--One valve above and one to side of cylinder

   D. L-Head--Both valves to side of engine (valve in block)

   (NOTE: The F-Head and L-Head are not used much due to the trend toward valve-in-head engines.)

VII. Locations of turbulence chambers (Transparency 7)

   A. Chamber in cylinder head

   B. Chamber in piston

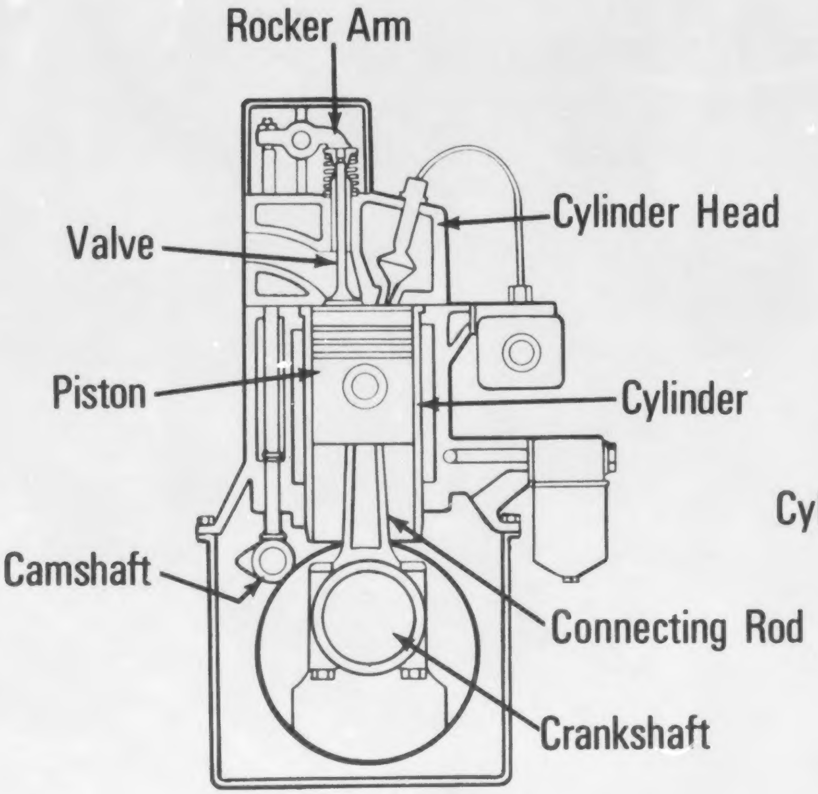
VIII. Forms of valves (Transparency 8)

   A. Standard

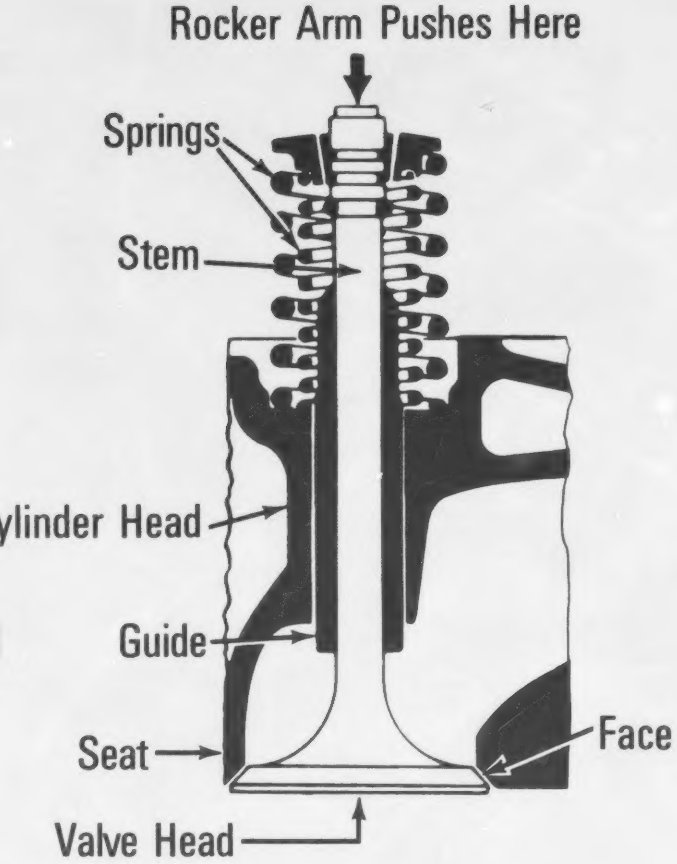
   B. Tulip

   C. Flat-top

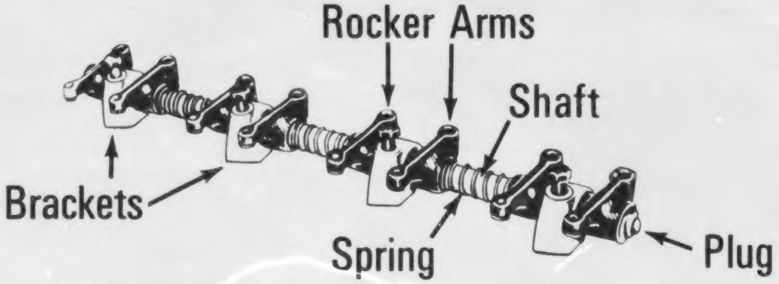
Valve Assembly

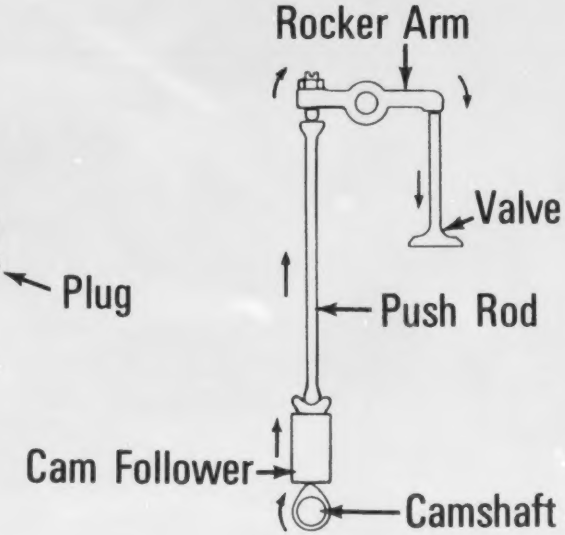

Rocker Arm
Cylinder Head
Valve
Piston
Cylinder
Camshaft
Connecting Rod
Crankshaft

In-Line Block

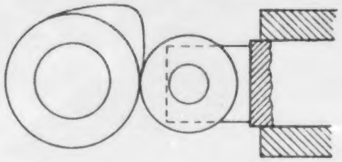

Rocker Arm Pushes Here
Springs
Stem
Cylinder Head
Guide
Seat
Face
Valve Head

Valve Rocker Arm Assembly

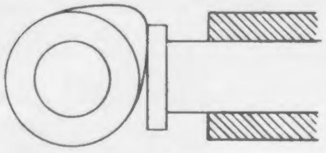

Rocker Arms
Shaft
Brackets
Spring
Plug


Rocker Arm
Valve
Push Rod
Cam Follower
Camshaft

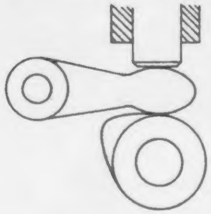
Roller-Type Follower



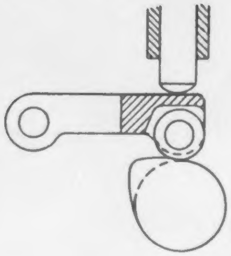
Flat or Mushroom Follower



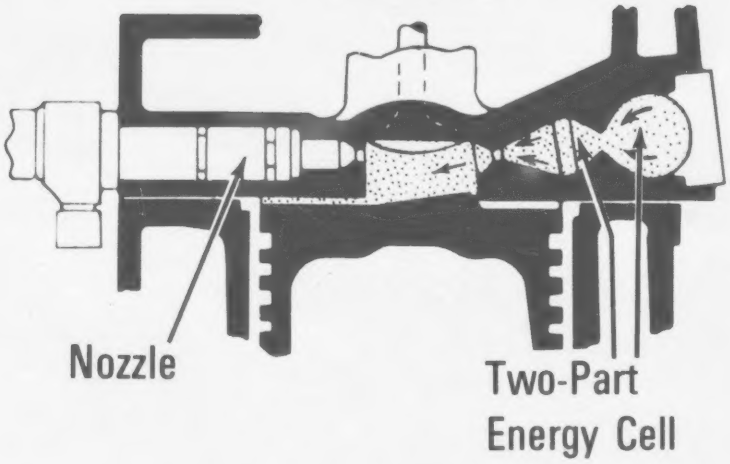
Pivoted Follower



Pivoted Pin Follower with Roller

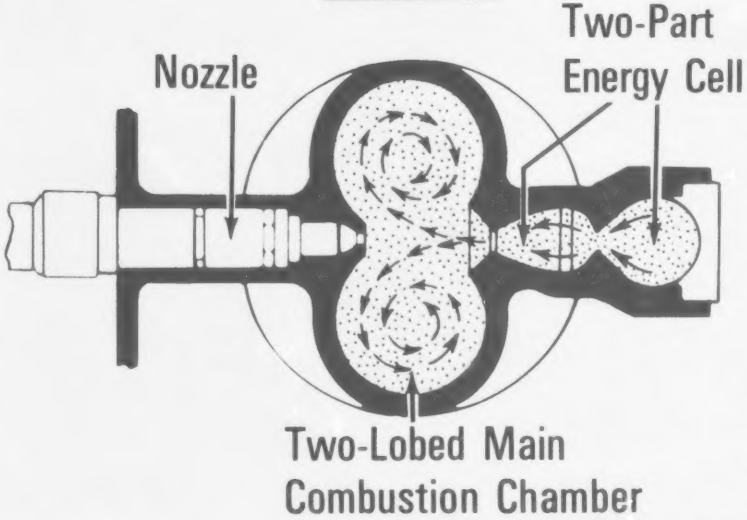


Energy Cell



Side View

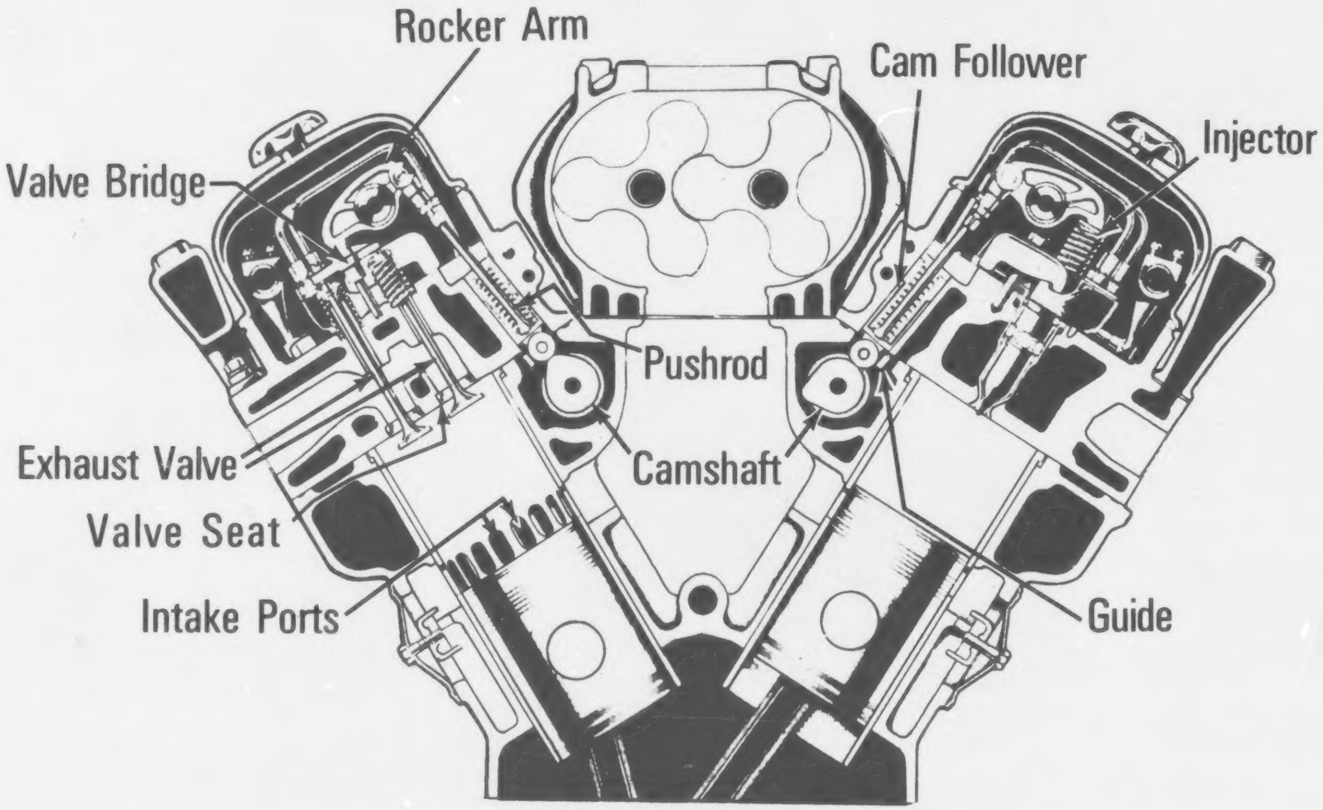
Nozzle
Two-Part Energy Cell



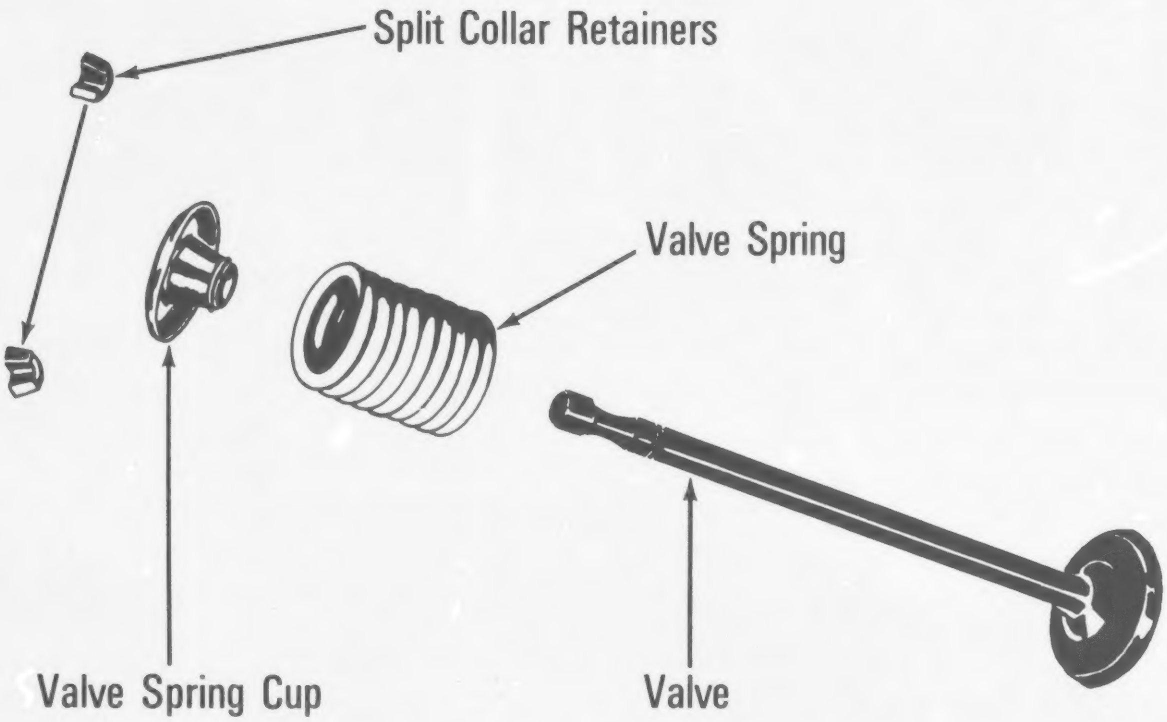
Top View

Nozzle
Two-Part Energy Cell
Two-Lobed Main Combustion Chamber

Valve and Fuel Injector


Rocker Arm
Cam Follower
Injector
Valve Bridge
Pushrod
Camshaft
Exhaust Valve
Valve Seat
Intake Ports
Guide

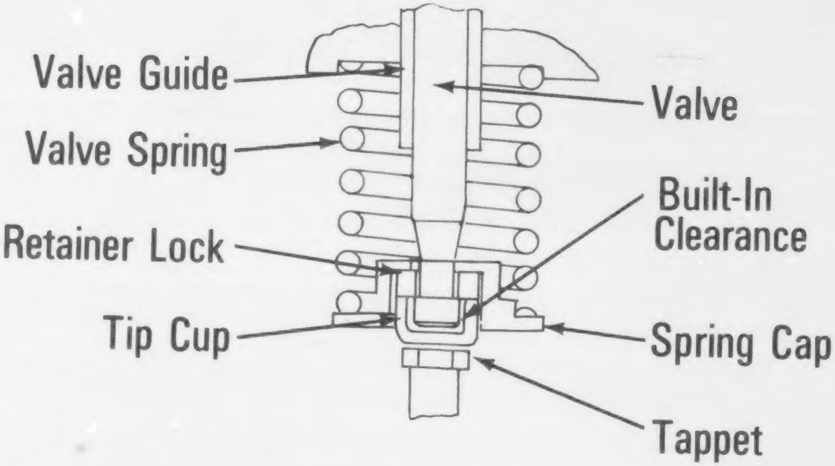
Primary Parts of a Valve Assembly


Split Collar Retainers
Valve Spring
Valve Spring Cup
Valve

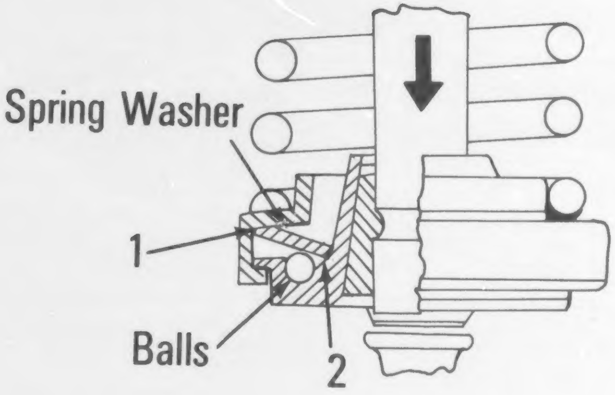
TM 5

D:F - 17-C

Valve Rotators


Valve Guide
Valve
Valve Spring
Built-In Clearance
Retainer Lock
Tip Cup
Spring Cap
Tappet

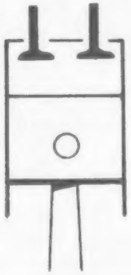
Release–Type


Spring Washer
1
Balls
2

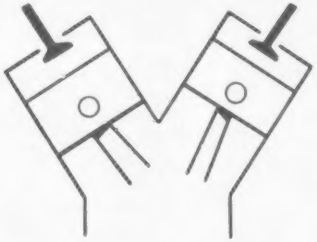
Positive–Type

Valve Arrangements and Turbulence Chambers

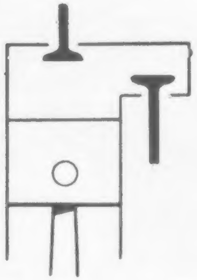
I-Head



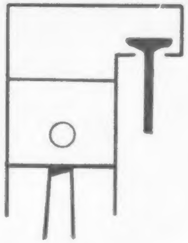
H-Head



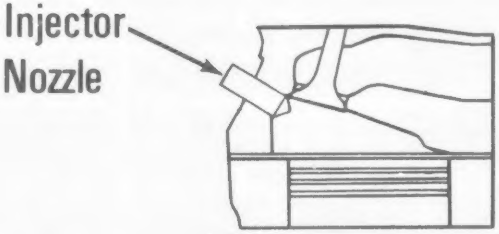
F-Head



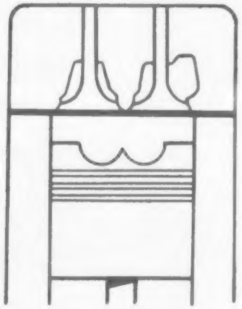
L-Head



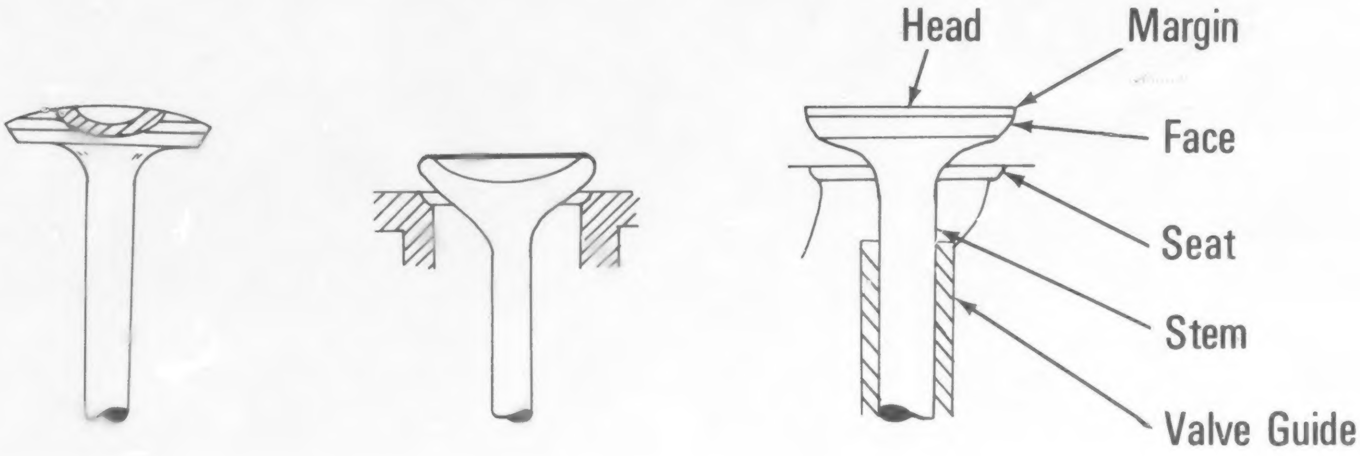
Turbulence Chamber
in Cylinder Head



Turbulence Chamber
in Top of Piston



Forms of Engine Valves


Head
Margin
Face
Seat
Stem
Valve Guide

Standard Tulip Flat-Top

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #1–REMOVE, INSPECT, AND INSTALL A CYLINDER HEAD

I. Tools and materials

- A. Steam supply
- B. Compressed air supply
- C. Chain hoist of sufficient capacity
- D. Brass hammer
- E. Torque wrench
- F. Straight edge
- G. Feeler gauge
- H. Head gasket scraper
- I. Wire brush
- J. Basic hand tool set
- K. New head gasket
- L. Shop towels
- M. Eye protection

  (NOTE: Valve springs are under pressure and wire brush bristles can come loose and damage your eyes.)

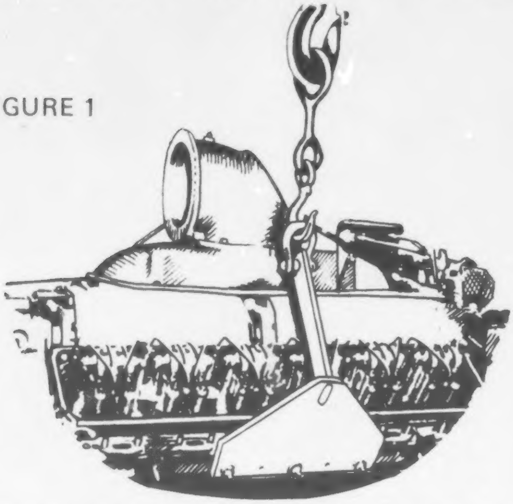
II. Procedure

- A. Remove cylinder head
  1. Check for oil, water, fuel, or compression leaks around cylinder head
  2. Steam clean the engine
  3. Drain coolant from engine
  4. Remove accessories attached to cylinder head, allowing a clear place to work

JOB SHEET #1

5. Remove rocker arm cover and rocker arm assembly, if used
6. Remove cylinder head studs as suggested by manufacturer's specifications
7. Attach suitable lifting device to head (Figure 1)

FIGURE 1



8. Break head loose using suitable pry bar and location

   (CAUTION: Do not pry on the contact surfaces.)

9. Place cylinder head in head holding fixture or equivalent and reinstall accessories

B. Inspect cylinder head

1. Clean the cylinder head and contact surfaces
2. Clean mating surfaces of the block and head thoroughly
3. Check for damage to the sealing surfaces of the head or block
4. Check liner protrusion for proper specification
5. Clean all carbon deposits from the head by scraping or brushing with a wire brush
6. Check for lime deposits in water passages and remove soft plug, if used

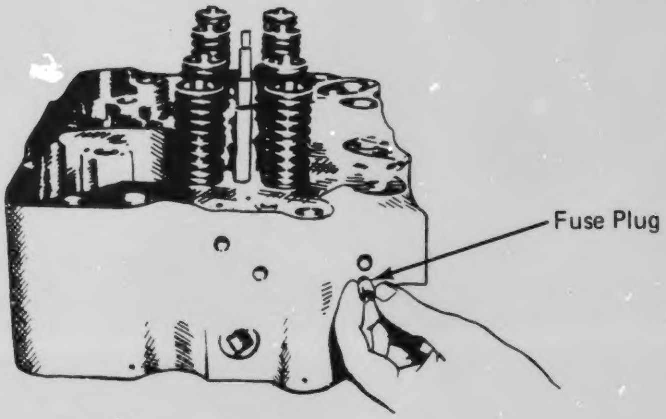
   (NOTE: Use a recommended solution and dip the head to clean out scale and lime.)

JOB SHEET #1

7. Examine fuse plug for signs of overheating (Figure 2)

   (NOTE: Fuse plugs contain a metal alloy center that melts if engine is overheated.)

FIGURE 2



8. Inspect and replace soft plug as needed

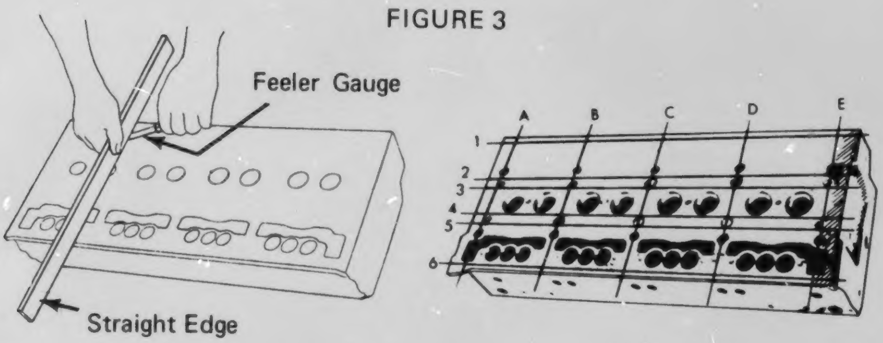
9. Install new plug if metal alloy has melted

   (NOTE: If fuse plug has melted, check carefully for further damage.)

10. Use a heavy straight edge and feeler gauge to check for warpage at each end and between all cylinders

    (NOTE: Also check for end-to-end warpage in at least six places. See Figure 3.)

FIGURE 3



JOB SHEET #1

11. Decide whether to reinstall head or reface it

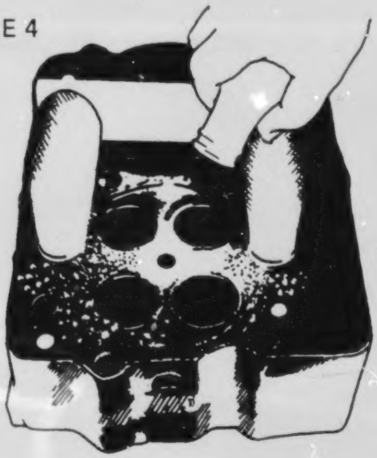
    (NOTE: Consult the engine technical manual for refacing limits.)

12. Check head for leaks or cracks

    a. Water and air pressure method--Seal the head and connect to an air hose. Immerse in hot water (180 - 2[illegible] F) for fifteen minutes. Leaks are detected by any air bubbles which appear in the water

    b. Magnetic crack detector method--The magnetic crack detector is placed over the suspected area, setting up a magnetic field (Figure 4)

FIGURE 4



(NOTE: Fine white metallic powder is then sprinkled over the area and the tool is rotated 90 degrees. After excess powder is blown off, any cracks are clearly shown in white.)

C. Install cylinder head

1. Inspect the cylinder head and contact surfaces
2. Inspect for scratches or nicks on the sealing surfaces of the head and block
3. Inspect and clean cylinder head cap screws and threads

JOB SHEET #1

4. Install new cylinder head gasket

   (NOTE: Follow engine manufacturer's recommendation for applying a sealing compound to one or both sides of the head gasket. Check to be sure that water passage holes are aligned with holes in block. Use aligning dowels if required.)

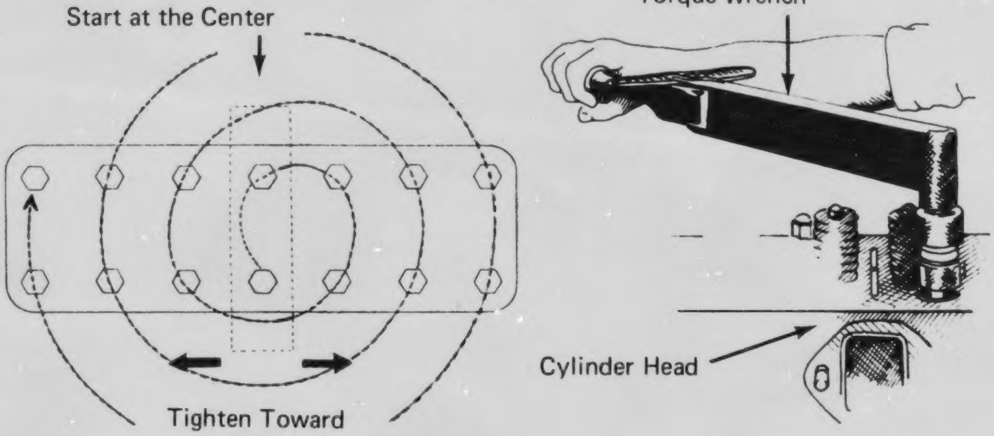
5. Set head squarely on block without disturbing the head gasket

6. Clean and lightly oil bolts or studs

7. Start the stud nuts or cap screws and tighten down finger tight

8. "Snug" down in the correct sequence (see manufacturer's manual) from center of head out (Figure 5)

FIGURE 5


Start at the Center
Torque Wrench
Cylinder Head
Tighten Toward Each End, Alternating from Side to Side in a Circle as Shown

9. Tighten each nut

   (NOTE: Refer to engine manual for torquing procedures. After the engine has been running a few hours, retighten the stud nuts in the correct sequence with the torque wrench.)

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #2--DISASSEMBLE AND SERVICE A VALVE TRAIN

I. Tools and materials

   A. Valve spring compressor

   B. Steam supply

   C. Compressed air supply

   D. Bench grinder

   E. 0-1 inch micrometer

   F. Valve spring tester

   G. Dial indicator

   H. Basic hand tool set

   I. Board with set of numbered holes for valves

   J. Crocus cloth

   K. Eye protection

II. Procedure

   A. Remove valve

      1. Steam clean complete head assembly

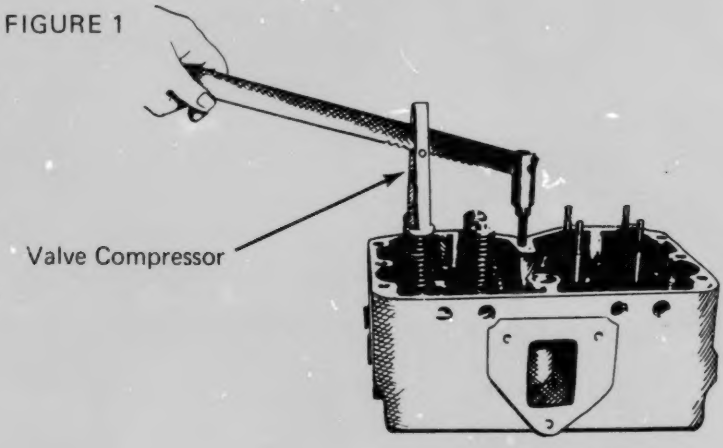
      2. Dry with compressed air

      3. Place cylinder head in head holding device or equivalent

JOB SHEET #2

4. Compress one valve spring at a time with valve compressor (Figure 1)

FIGURE 1


Valve Compressor

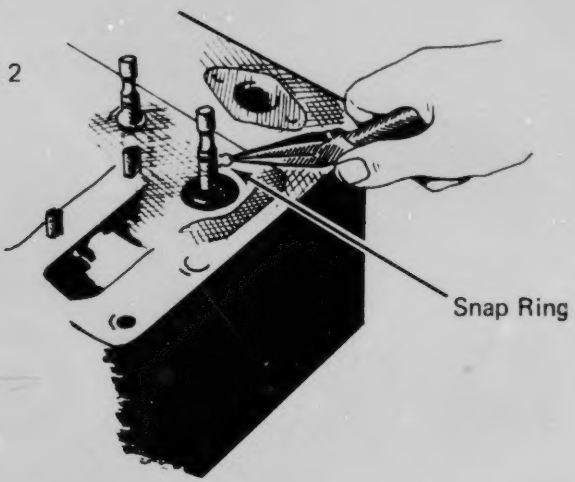
5. Tap valve lightly to loosen; then remove split collar retainers

6. Remove spring cup

7. Remove spring

8. Remove snap ring and seal, if used (Figure 2)

FIGURE 2



JOB SHEET #2

9. Remove valve from bottom of cylinder head

10. Use a board with a set of numbered holes drilled in it and place valves in holes in their correct order

    (CAUTION: Do not mix.)

B. Clean valves

1. Hold each valve firmly against a wire wheel on a bench grinder, or use glass bead or sandblast method

2. Remove all carbon from valve head, face, and stem

3. Polish valve stems with crocus cloth

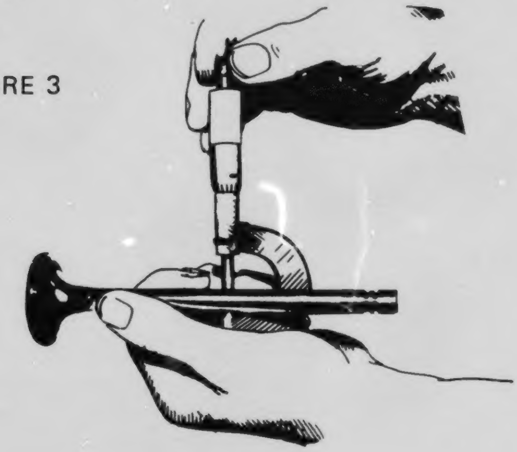
   (NOTE: Do not use wire brush on stem bearing surface.)

C. Inspect and test valves

1. Inspect valves

   a. Use 0-1 inch micrometer to measure the valve stem (Figure 3)

FIGURE 3



   b. If diameter is less than specified in manufacturer's manual, discard valve and valve guide

      (NOTE: See Job Sheet #3 for valve guide replacement.)

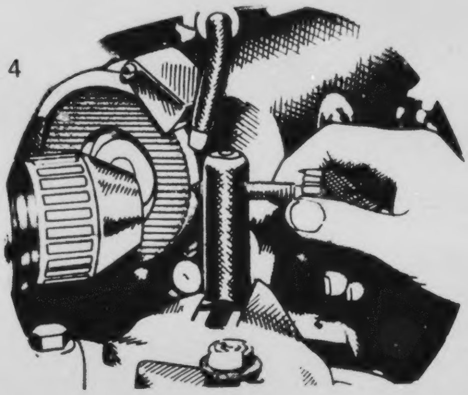
JOB SHEET #2

2. Test valves
    a. Hold the valve by the stem, head down
    b. Strike sharply on stem end with hammer; if fracture exists, the head will break off

D. Reface valves

1. Dress wheel, if necessary (Figure 4)

FIGURE 4

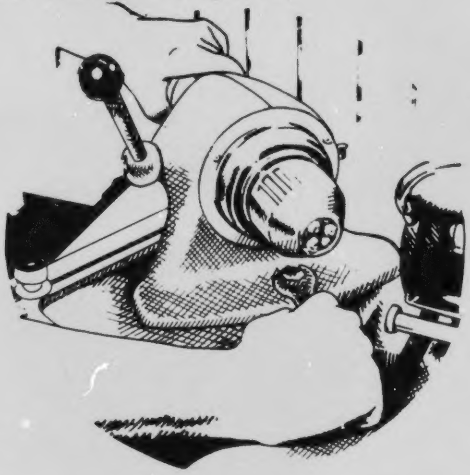


    a. Place dressing attachment against stop bar on grinding head and tighten wing nut
    b. Turn on motor and take light, steady cuts across wheel

    (NOTE: Use coolant as required by manufacturer.)

2. Locate chuckhead (Figure 5)

FIGURE 5



JOB SHEET #2

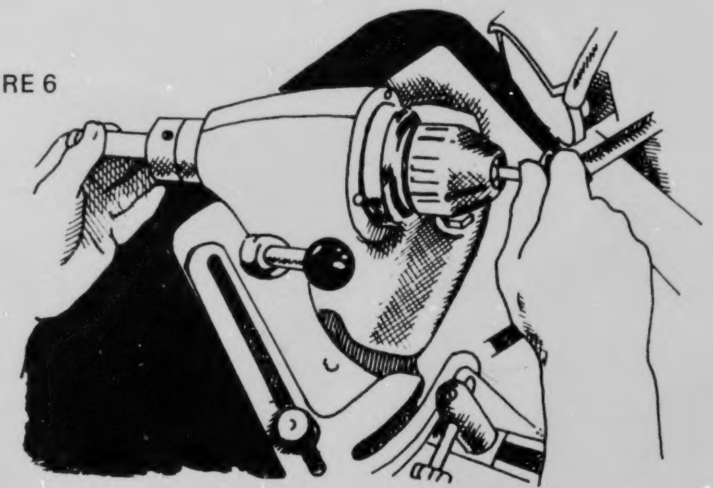
a. Locate chuckhead at the exact angle you wish to refinish valve

(NOTE: Refer to manufacturer's specifications.)

b. Lock chuckhead with hex nut

3. Chuck valve (Figure 6)

FIGURE 6



(CAUTION: Special care should be taken when working with sodium filled exhaust valves.)

a. Open chuck sleeve and insert valve so that rollers touch just above the worn part of the stem

b. Set aligner for proper length of valve

c. Close chuck sleeve to contact stem

d. Depress lever and close chuck sleeve about 1/8 turn

(NOTE: Use according to manufacturer's specifications.)

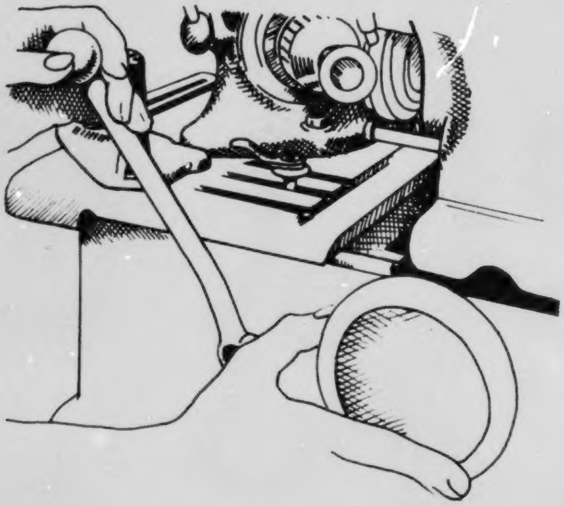
e. Press valve firmly back into aligner and release lever

f. Tighten by hand to desired tension

JOB SHEET #2

4. Grind valves (Figure 7)

FIGURE 7



a. Switch on motor

b. Advance valve in front of grinding wheel until wheel just touches valve

   (NOTE: Adjust coolant nozzle as required.)

c. Set micrometer on feed screw at zero

d. Begin grinding at left side of wheel, moving valve slowly and steadily across wheel then back again

e. Take light cuts by feeding the wheel up to the valve .001 or .002 at a time

f. Remove just enough material to make a clean, smooth face

g. When valve face is trued, advance to right until top edge of valve is flush with right hand edge of wheel

   (CAUTION: Do not let valve leave the stone.)

JOB SHEET #2

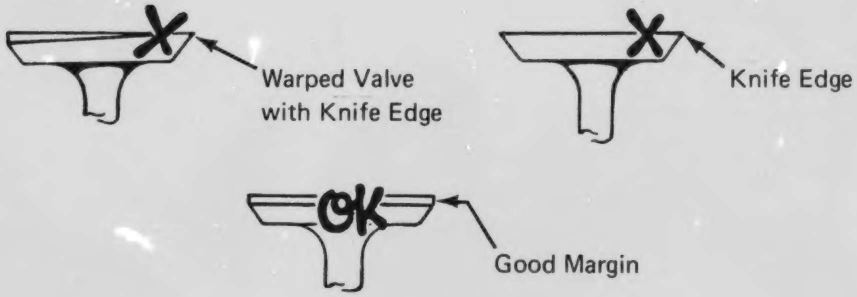
h. Stop a second or two, then back grinding wheel away from valve

i. Repeat steps above for other valves

(NOTE: Keep valves in numbered rack to make sure you return them to their own guides.)

j. Replace any valve that cannot be entirely refaced while keeping a good valve margin (Figure 8)

FIGURE 8



(CAUTION: Avoid a knife edge around part or all of the valve head. See Figure 8.)

E. Inspect valve spring

1. Inspect for:

   a. Wear on the casting where springs rotate

   b. Wear on the spring caps

   c. Wear on ends of spring

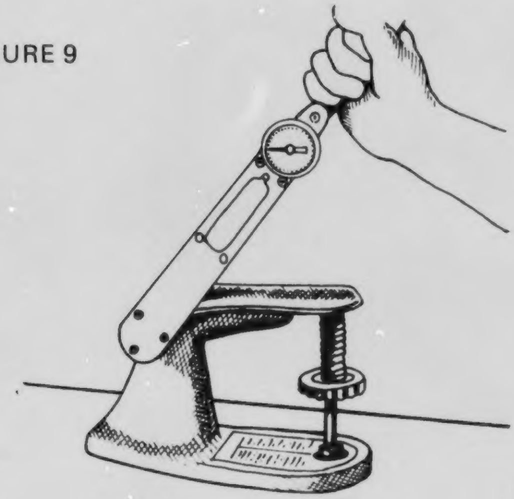
   d. Warped springs

JOB SHEET #2

2. Test spring tension

   a. Mount valve spring on spring tester (Figure 9)

FIGURE 9



   b. Measure spring length by means of manufacturer's standards

   c. Compress valve spring

   (NOTE: If valve springs compress to dimensions shown in manufacturer's table at less than load indicated under "worn limits," valve spring should be discarded.)

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #3--SERVICE VALVE GUIDES

I. Tools and materials

- A. Basic hand tool set
- B. Electric hand drill
- C. Rotary wire cleaning brush
- D. Valve seat grinding kit
- E. 0-1 inch micrometer
- F. Small bore gauge
- G. Bluing or lead pencil
- H. Shop towels
- I. Safety glasses
- J. Appropriate service manual

II. Procedure

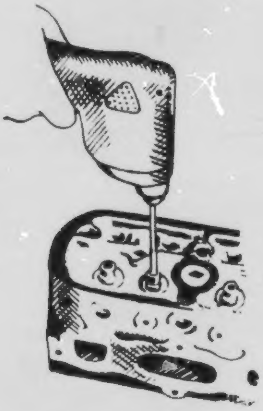
(CAUTION: Follow all shop safety procedures.)

- A. Service valve guides
  - 1. Clean valve guides
    - a. Use correct size wire brush in an electric drill

JOB SHEET #3

b. Run brush up and down the full length of guide (Figure 1)

FIGURE 1

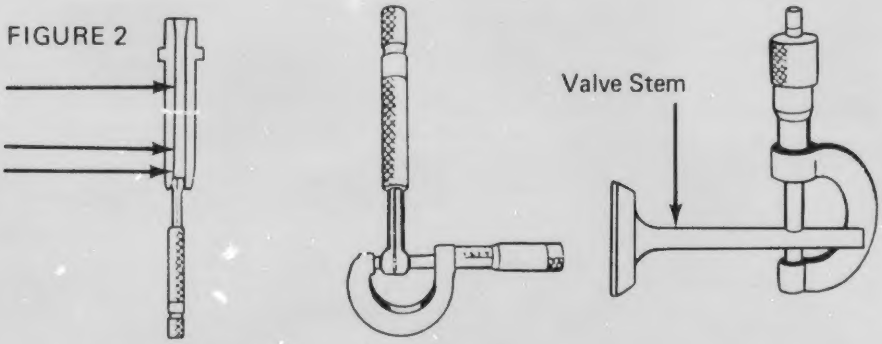


c. Apply a few drops of oil

2. Inspect valve guides

a. Measure at different points within the guide (Figure 2)

FIGURE 2



Measure Inside of
Guide with Gauge

b. Read measurement with micrometer

c. Measure outside of valve stem (Figure 2)

d. Compare (b) and (c) for clearance

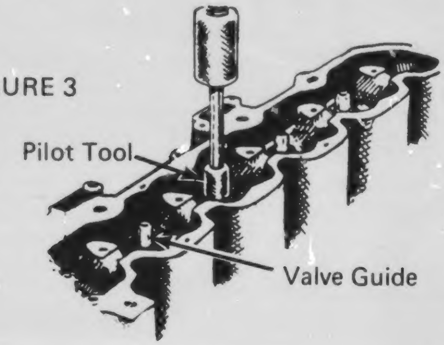
(NOTE: If guide to stem clearance is more than 50 percent above manufacturer's specifications, replace or knurl and ream the valve guide.)

JOB SHEET #3

3. Replace valve guides

   a. Remove old valve guide and install new guides as needed (Figure 3)

FIGURE 3



   (NOTE: Some guides may compress slightly when installed.)

   b. Precision-ream to specifications after installation, if required

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #4--SERVICE VALVE SEATS

I. Tools and materials

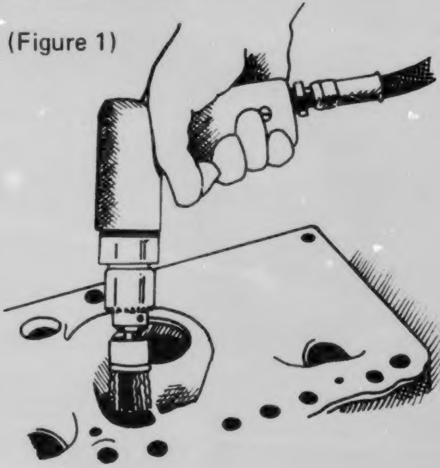
- A. Basic hand tool set
- B. Electric hand drill
- C. Rotary wire cleaning brush
- D. Valve seat grinding kit
- E. 0-1 inch micrometer
- F. Small bore gauge
- G. Bluing or lead pencil
- H. Shop towels
- I. Safety glasses
- J. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Clean valve seats (Figure 1)

FIGURE 1



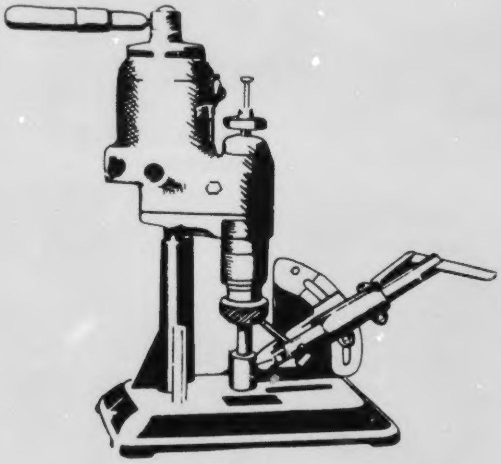
1. Use an electric hand drill with wire brush to remove all carbon
2. Apply kerosene to loosen carbon
3. Check for pitted, burned, or worn seat

JOB SHEET #4

B. Dress grinding wheel

1. Set dressing tool at desired angle (Figure 2)

FIGURE 2



2. Put a drop of very light oil on dressing pilot

   (CAUTION: Do not get oil on grinding wheel.)

3. Screw grinding wheel on holder and place on pilot
4. Adjust until wheel just touches diamond
5. Insert driver and bring up to speed
6. Move diamond steadily across wheel, taking light cuts

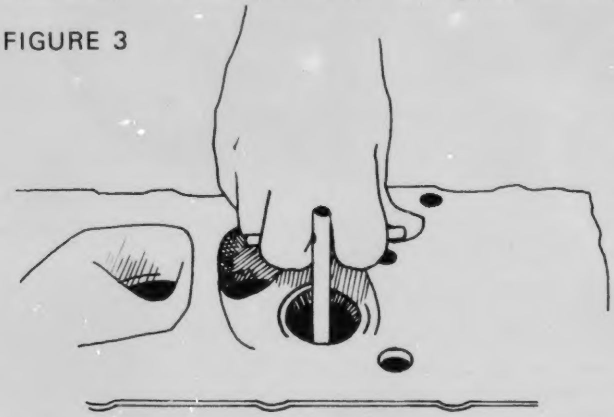
C. Select tapered pilot (Figure 3)

1. Select largest pilot which will fit snugly into valve guide

JOB SHEET #4

2. Place drop of oil on pilot, insert into guide, and twist gently to lock

FIGURE 3

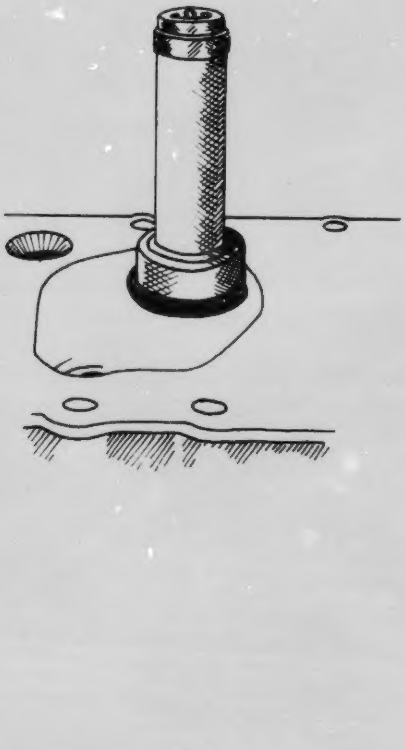


D. Select grinding wheel

1. Screw proper grinding wheel onto holder and place on pilot (Figure 4)

(NOTE: Refer to service manual for size and angle.)

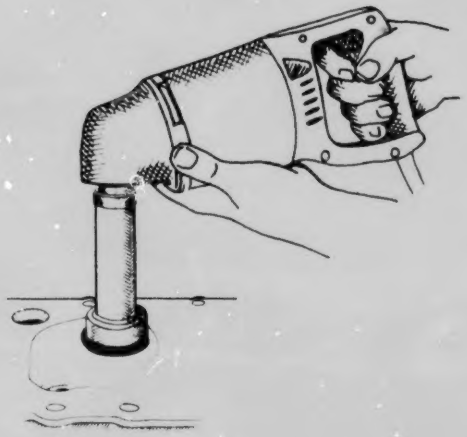
FIGURE 4



JOB SHEET #4

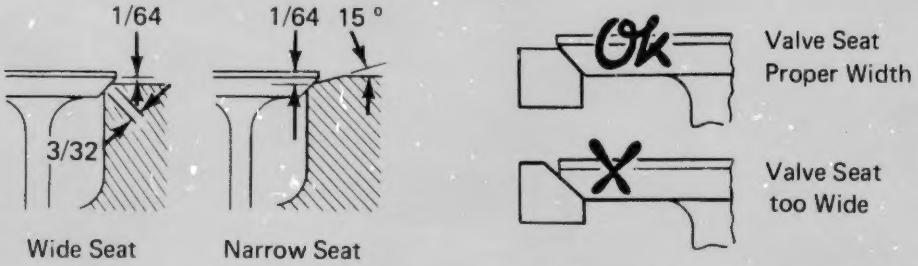
2. Insert driver spindle in holder (Figure 5)

FIGURE 5



3. Grind the valve seat so that little of the valve face is exposed to the combustion chamber (Figure 6)

FIGURE 6


1/64
3/32
1/64
15 °
Ok
Valve Seat Proper Width
X
Valve Seat too Wide

Wide Seat

Narrow Seat

(NOTE: Narrow seat to manufacturer's specifications.)

4. Precautions

   a. Do not grind too long, only a few seconds

   b. Do not use too much pressure

   c. Keep work area clean

   d. Check seat width and contact pattern with bluing or lead pencil marks

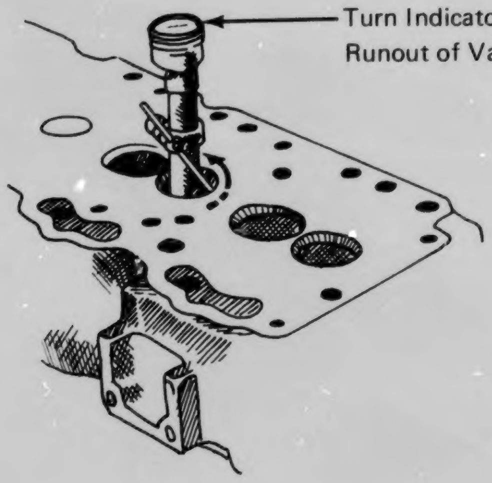
   e. Regrind uneven spots

   (NOTE: Lap seats with grinding compound only if necessary.)

JOB SHEET #4

f. Check the runout (concentricity) of the valve seat with a dial indicator (Figure 7)

FIGURE 7



Turn Indicator to Check Runout of Valve Seat

(NOTE: Reading must be within specifications shown in the engine technical manual.)

g. Rotate the pilot 90° in the guide and take a second reading

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #5--SERVICE VALVE SEAT INSERTS

I. Tools and materials

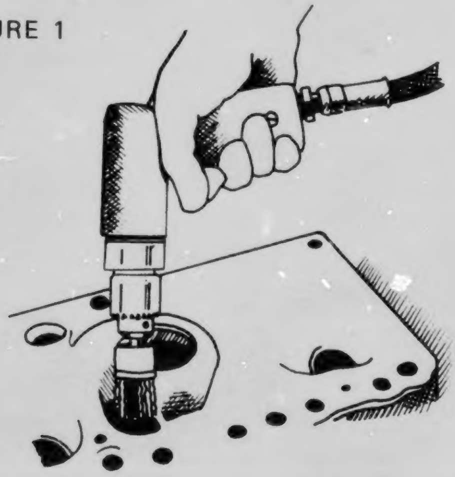
- A. Basic hand tool set
- B. Electric hand drill
- C. Rotary wire cleaning brush
- D. Shop towels
- E. Safety glasses
- F. Valve seat insert puller
- G. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Clean valve seats (Figure 1)

FIGURE 1



1. Use an electric drill with wire brush to remove all carbon
2. Apply kerosene to loosen carbon
3. Check for pitted, burned, or worn seat

JOB SHEET #5

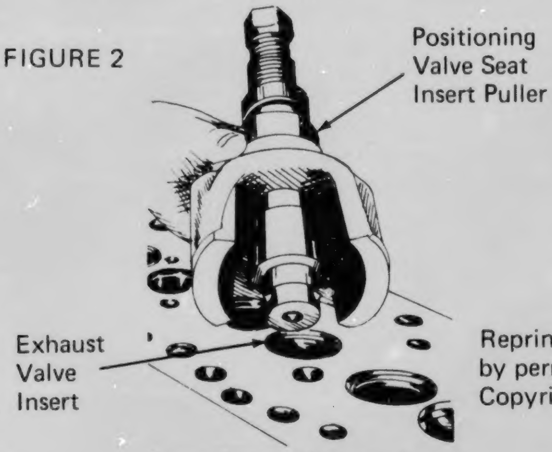
B. Check the valve seat insert for cracks or looseness by lightly tapping the cylinder head near the insert

(NOTE: If insert is loose enough to bounce, mark for replacement.)

C. Remove valve seat insert

1. Use a valve seat insert puller (Figure 2)

FIGURE 2



Reprinted from *Diesel Mechanics* by permission of McGraw-Hill, Inc., Copyright 1977.

Removing a valve seat insert

(CAUTION: Do not use a prybar, punch, or chisel because the hardened materials shatter like glass and serious face or eye injury could result.)

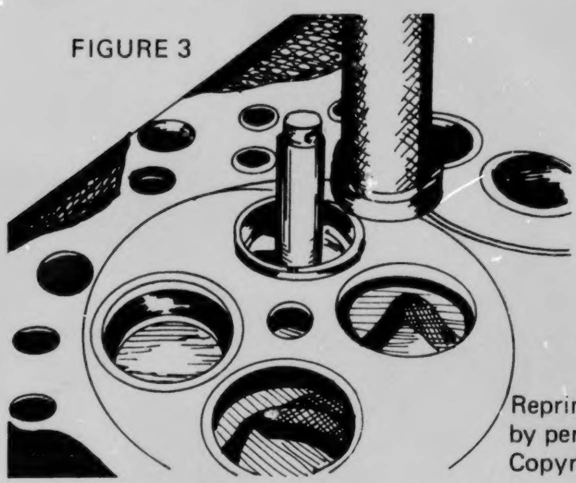
2. Upon removal, check the counterbore for burrs, cracks, or rough edges

JOB SHEET #5

D. Install valve seat insert

1. Drive or press the insert down tightly into the counterbore by using an insert driver (Figure 3)

FIGURE 3



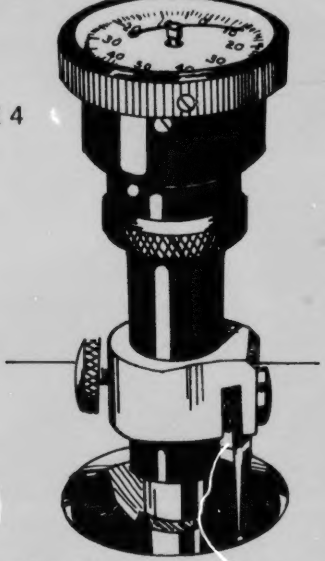
Reprinted from *Diesel Mechanics* by permission of McGraw-Hill, Inc., Copyright 1977.

Installing a valve seat insert

2. Check to see that insert is fully seated

3. Check valve seat runout (Figure 4)

FIGURE 4



Reprinted from *Diesel Mechanics* by permission of McGraw-Hill, Inc., Copyright 1977.

Measuring valve seat runout

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #6--ASSEMBLE A CYLINDER HEAD

I. Tools and materials

- A. Basic hand tool set
- B. Valve spring compressor
- C. Shop towels
- D. Feeler gauges
- E. Straight edge
- F. Safety glasses
- G. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Assemble cylinder head

1. Apply oil to to valve stems and return to same ports from which they were removed

   (NOTE: Commercial valve stem lubricants are available.)

2. Work the valves back and forth to make sure they slip through easily and seat properly

   (NOTE: A properly seated valve will bounce when dropped on its seat.)

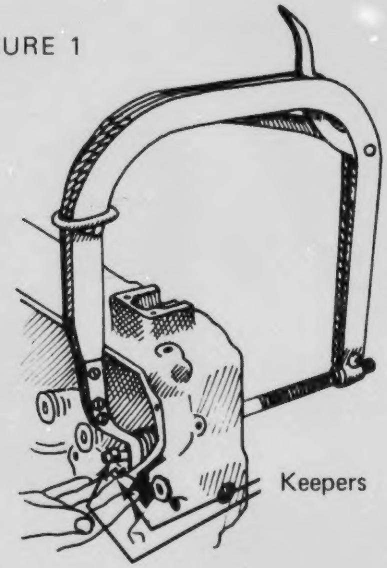
3. Install valve seals if required and seat valve springs

   (NOTE: Place wound end of spring to stationary side.)

JOB SHEET #6

4. Install new valve keepers, if necessary, making sure they fit properly (Figure 1)

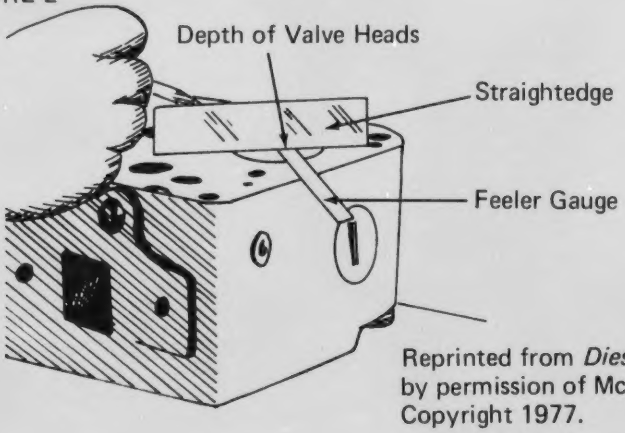
FIGURE 1



5. Pop each spring and valve assembly three or four times by tapping on the end with a soft mallet

B. Check valve head height (Figure 2)

FIGURE 2


Depth of Valve Heads
Straightedge
Feeler Gauge

Reprinted from *Diesel Mechanics* by permission of McGraw-Hill, Inc., Copyright 1977.

Measuring valve head height.

CYLINDER HEAD ASSEMBLY
UNIT I

NAME______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. To clean, inspect, lubricate, and/or adjust

______b. Disk with a stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring

______c. That part in the head upon which the valve face rests to close the port

______d. Hole through which the stem of the valve passes

______e. Helical spring used to close the valve

______f. Hold the valve spring on the valve stem

______g. Lever that transmits the action of the cam to the stem of the valves

______h. Serves as a fulcrum for rocker arms

______i. Shaft, rocker arm, and cam follower

______j. Intermediate contact between camshaft and valve stem

______k. Special removable combustion chamber for high speed diesel engines

______l. High velocity swirling of air within the combustion chamber

______m. Angle between the seat surface and the cylinder head surface, either 30 or 45 degrees

______n. A twisting effort

1. Valve guide
2. Cam follower
3. Rocker arm
4. Rocker arm shaft
5. Valve spring retainers
6. Service
7. Rocker arm assembly
8. Valve seat
9. Poppet valve
10. Valve spring
11. Valve seat angle
12. Energy cell
13. Foot-pound
14. Fuel injector

______	o. Wrench used to draw nuts to a specified tension by measuring the twisting effort in foot-pounds	15.	Torque wrench
______	p. Equivalent to raising one pound a distance of one foot	16.	Turbulence
______	q. Meters and sprays fuel into the combustion chamber	17.	Torque
______	r. Injects fuel under high pressure	18.	Fuel injection nozzle

2. Name five major parts usually found in a cylinder head assembly.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

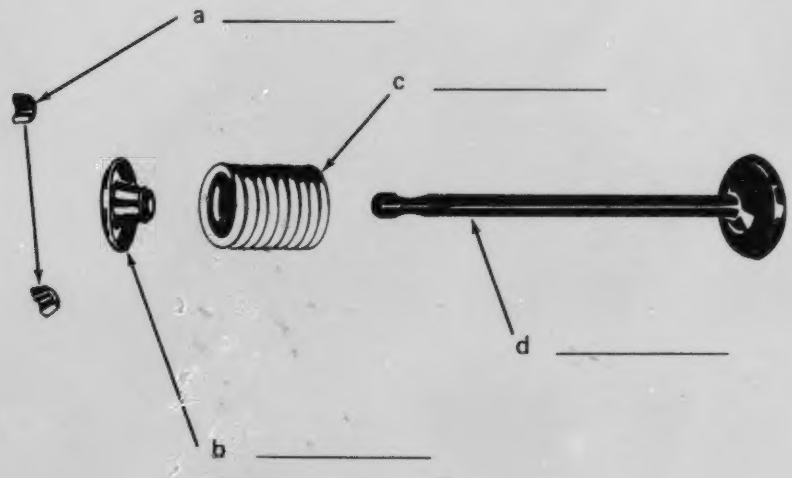
3. Name three forms of cylinder head castings that may be found on a diesel engine.

a. ______________________________

b. ______________________________

c. ______________________________

4. Identify the primary parts in a valve assembly.



5. List two types of valve rotators.

a. ____

b. ____

6. Match the valve arrangements on the left with the types of engine heads.

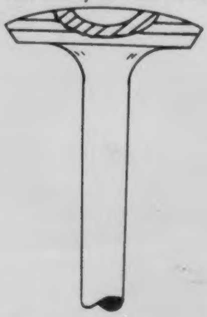
______a. Both valves to side of engine	1. F-Head
______b. Both valves above angled cylinders	2. L-Head
______c. Both valves above cylinder	3. I-Head
______d. One valve above and one to side of cylinder	4. H-Head

7. List two locations for turbulence chambers in the engine.

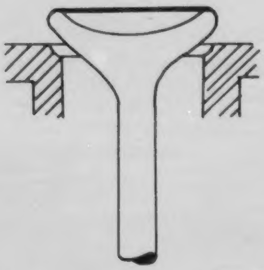
a. ____

b. ____

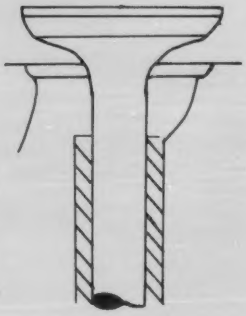
8. Identify three forms of engine valves.



a. ____________



b. ____________



c. ____________

9. Demonstrate the ability to:

a. Remove, inspect, and install a cylinder head.

b. Disassemble and service a valve train.

c. Service valve guides.

d. Service valve seats.

e. Service valve seat inserts.

f. Assemble a cylinder head.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

CYLINDER HEAD ASSEMBLY
UNIT I

ANSWERS TO TEST

1. a. 6
   b. 9
   c. 8
   d. 1
   e. 10
   f. 5
   g. 3
   h. 4
   i. 7
   j. 2
   k. 12
   l. 16
   m. 11
   n. 17
   o. 15
   p. 13
   q. 14
   r. 18

2. Any five of the following:

   a. Intake valve
   b. Exhaust valve
   c. Rocker arm
   d. Fuel injector or nozzle
   e. Cam followers
   f. Fuel injector tube
   g. Valve guides
   h. Valve seats

3. a. Single
   b. Multiple
   c. One piece

4. a. Split collar retainers (valve keepers)
   b. Valve spring cup
   c. Valve spring
   d. Valve

5. a. Release type
   b. Positive type

6. a. 2
   b. 4
   c. 3
   d. 1

7. a. Chamber in cylinder head
   b. Chamber in piston

8. a. Standard
   b. Tulip
   c. Flat-top

9. Performance skills evaluated to the satisfaction of the instructor

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the primary parts of a piston and connecting rod assembly and select the causes of high oil consumption and blow-by. The student should also be able to inspect and measure pistons and crankshaft for wear. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with piston and connecting rod assemblies with the correct definitions.
2. Identify seven primary parts of a piston and connecting rod assembly.
3. List three functions of the piston.
4. Identify five main parts of a piston.
5. List three functions of piston rings.
6. Name the two types of piston rings.
7. Name three common types of ring joints.
8. Select possible causes of high oil consumption and blow-by.
9. Identify three types of piston pins.
10. Name two types of construction for the cap end of a connecting rod.
11. Complete a list of statements concerning the reasons for markings on the connecting rod, piston, and bearing cap.
12. Demonstrate the ability to:
    - a. Remove piston and connecting rod assembly.
    - b. Remove piston rings and piston from rod.
    - c. Clean pistons.
    - d. Inspect and measure pistons for wear.
    - e. Install rings and assemble piston to rod.
    - f. Inspect piston pin and connecting rod bushing for serviceability.
    - g. Inspect and measure crankshaft for wear.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Have students list different coatings on rings.

VIII. Have students make a price list of items necessary to perform job sheets using their own car.

IX. Have students make a list of the different types of piston pin designs and their uses.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Piston and Connecting Rod Assembly

      2. TM 2–Piston Rings

      3. TM 3--Piston Ring Design

      4. TM 4--Blow-By

      5. TM 5--Types of Piston Pins

      6. TM 6--Connecting Rod Markings

D. Job Sheets

1. Job Sheet #1--Remove Piston and Connecting Rod Assembly
2. Job Sheet #2--Remove Piston Rings and Piston from Rod
3. Job Sheet #3--Clean Pistons
4. Job Sheet #4--Inspect and Measure Pistons for Wear
5. Job Sheet #5--Install Rings and Assemble Piston to Rod
6. Job Sheet #6--Inspect Piston Pin and Connecting Rod Bushing for Serviceability
7. Job Sheet #7--Inspect and Measure Crankshaft for Wear

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. 3rd ed. Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines*. 5th ed. Moline, Illinois: Deere and Company, 1980.

C. *Cummins Engine Shop Manual*. Columbus, Indiana: Cummins Engine Company, 1974.

D. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Piston skirt--Outside part of piston below ring grooves

   B. Piston land--Area between ring grooves

   C. Piston pin--Ties piston and rod together

   D. Piston pin boss--Hole in piston which supports piston pin

   E. Ring joints--Clearance between ends of piston rings

   F. Blow-by--Combustion gases escaping to the crankcase

   G. Lugging--Overloading, causing unusual stress

   H. Incandescent--Glowing or burning

   I. Knurling--Upsetting the metal to decrease the inside diameter or increase the outside diameter

   J. Full floating pin--Piston pin that moves in both rod and piston

   K. Plastigage--Soft, oil soluble, plastic thread

II. Primary parts of a piston and connecting rod assembly (Transparency 1)

   A. Piston

   B. Piston rings

   C. Piston pin

   D. Piston pin bushing

   E. Connecting rod

   F. Connecting rod cap

   G. Bearing shells

III. Functions of a piston

   A. Receives the force of combustion

   B. Transmits this force to the crankshaft

   C. Carries the piston rings which seal and wipe the cylinder

INFORMATION SHEET

IV. Main parts of a piston (Transparency 1)

   A. Head or crown

   B. Skirt

   C. Ring grooves

   D. Lands

   E. Piston pin boss

V. Functions of piston rings

   A. Forms a gas tight seal between the piston and cylinder

   B. Helps cool the piston by transferring heat

   C. Controls lubrication between piston and cylinder wall

VI. Types of piston rings (Transparencies 2 and 3)

   A. Compression rings

   B. Oil control rings

VII. Common types of ring joints (Transparency 2)

   A. Step

   B. Angle

   C. Butt

VIII. Causes of high oil consumption and blow-by (Transparency 4)

   A. Piston rings installed wrong

   B. Stuck oil ring

   C. Plugged oil ring

   D. Top ring broken or top groove worn

   E. Overall wear in piston, rings, and cylinder

   F. Physical damage to pistons

INFORMATION SHEET

IX. Types of piston pins (Transparency 5)

  A. Fixed--Moves in rod, fastened to piston

  B. Semi-floating--Moves in piston, fastened to rod

  C. Full floating--Moves in both piston and rod, fastened by spring clips

X. Types of construction for the cap end of a connecting rod (Transparency 6)

  A. Square cut

  B. Angle cut

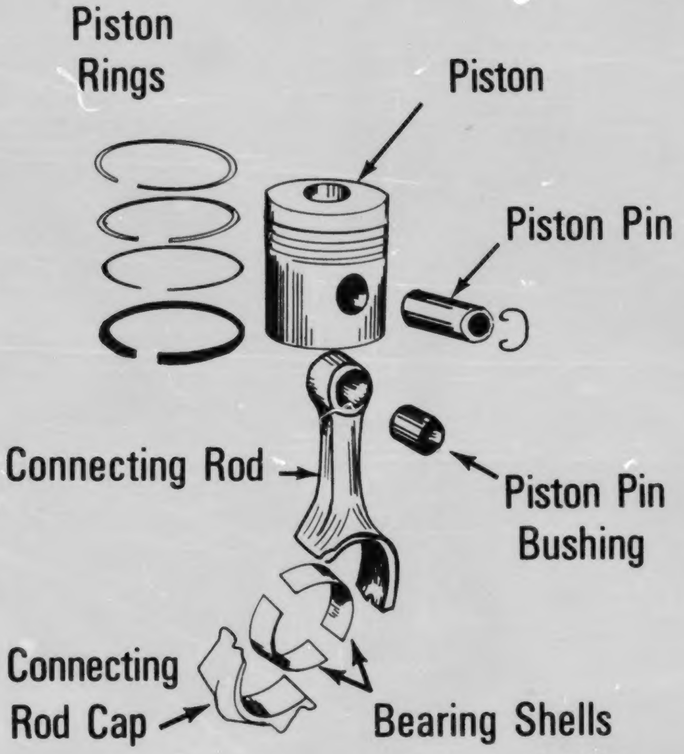
XI. Reasons for markings (Transparency 6)

  A. On the piston--To install in same cylinder and on same side from which removed

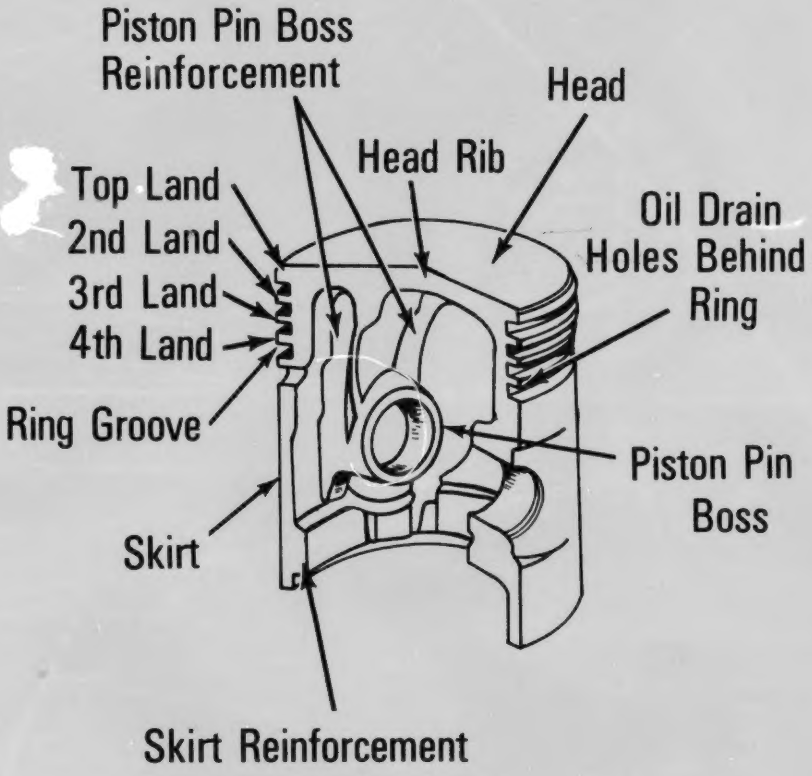
  B. On the connecting rod--To install in same cylinder and on same side from which removed

  C. On the bearing cap--To install on same rod and on same side from which removed

Piston and Connecting Rod Assembly

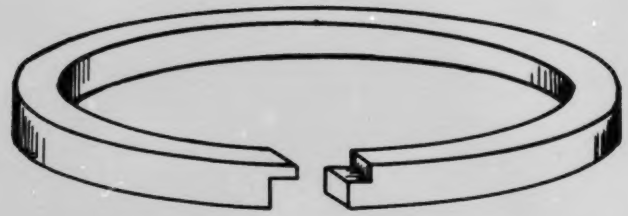

Piston Rings
Piston
Piston Pin
Connecting Rod
Piston Pin Bushing
Connecting Rod Cap
Bearing Shells

Complete Piston and Connecting Rod Assembly

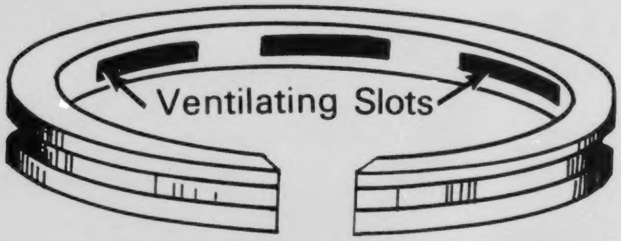

Piston Pin Boss Reinforcement
Head
Head Rib
Top Land
2nd Land
3rd Land
4th Land
Oil Drain Holes Behind Ring
Ring Groove
Piston Pin Boss
Skirt
Skirt Reinforcement

Piston

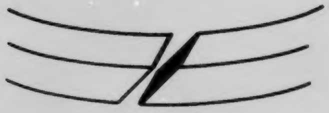
Piston Rings



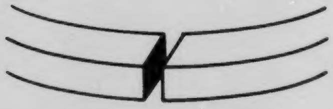
Compression Ring


Ventilating Slots

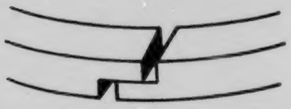
Double–land Beveled and Ventilated Oil Ring



45° Angle Joint

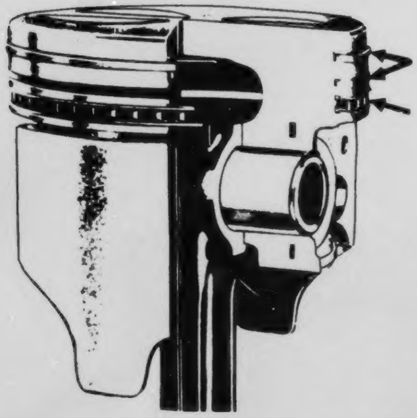


Butt Joint



Step Joint

Compression Rings with Simple Joints


Compression Rings
Oil Control Rings

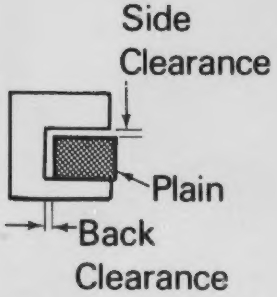
Piston Rings for a Typical Piston

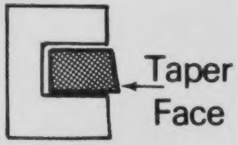
TM 2

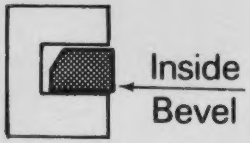
D:F - 71-C

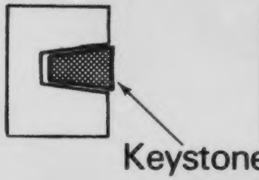
Piston Ring Design

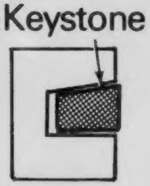
First Compression Rings

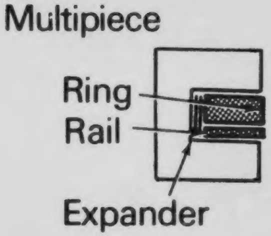

Side
Clearance
Plain
Back
Clearance



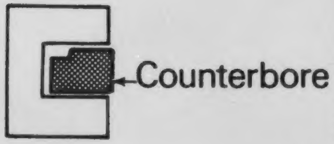

Inside
Bevel

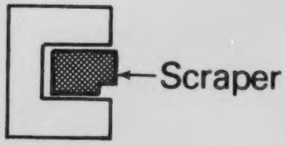


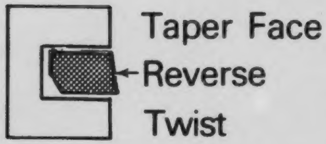


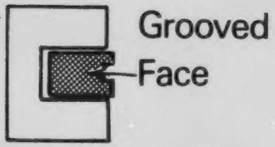

Multipiece
Ring
Rail
Expander

Second Compression Rings

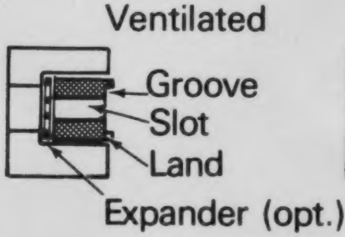

Counterbore

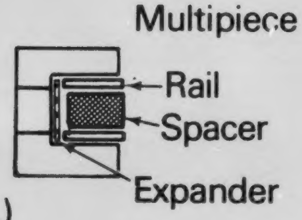


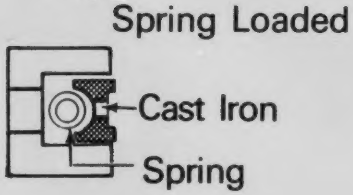

Taper Face
Reverse
Twist

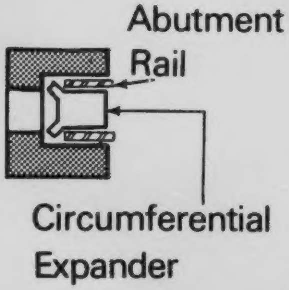

Grooved
Face

Oil Control Rings

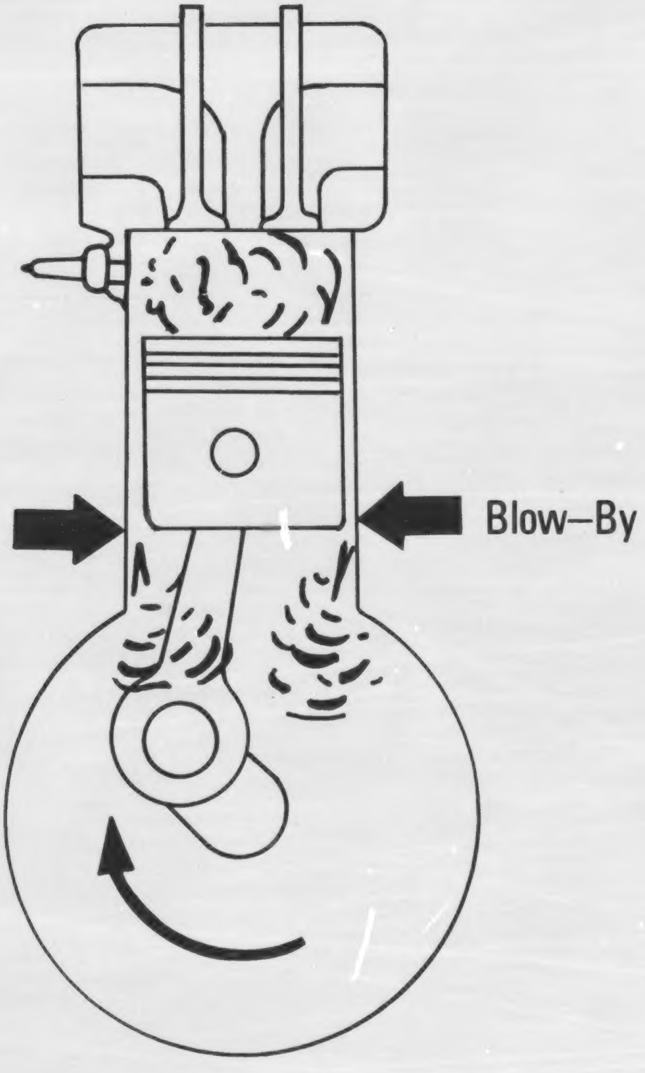

Ventilated
Groove
Slot
Land
Expander (opt.)


Multipiece
Rail
Spacer
Expander


Spring Loaded
Cast Iron
Spring

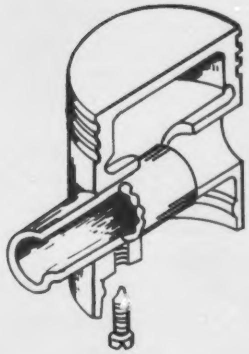

Abutment
Rail
Circumferential
Expander

Blow-By



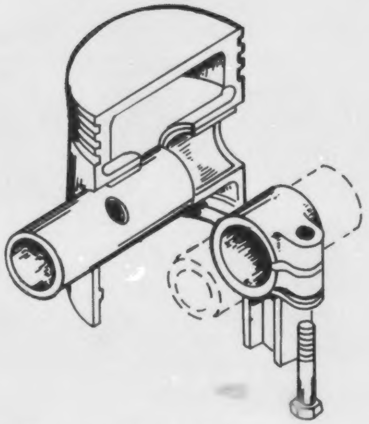
Blow–By of Gases in Cylinder

Types of Piston Pins



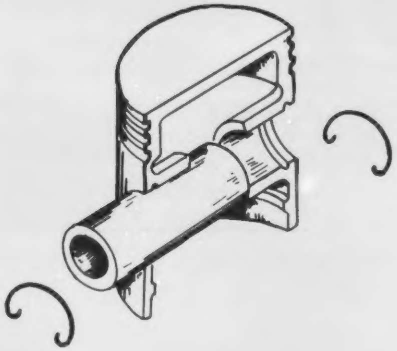
Fixed Pin

Fastened to Piston



Semi-Floating Pin

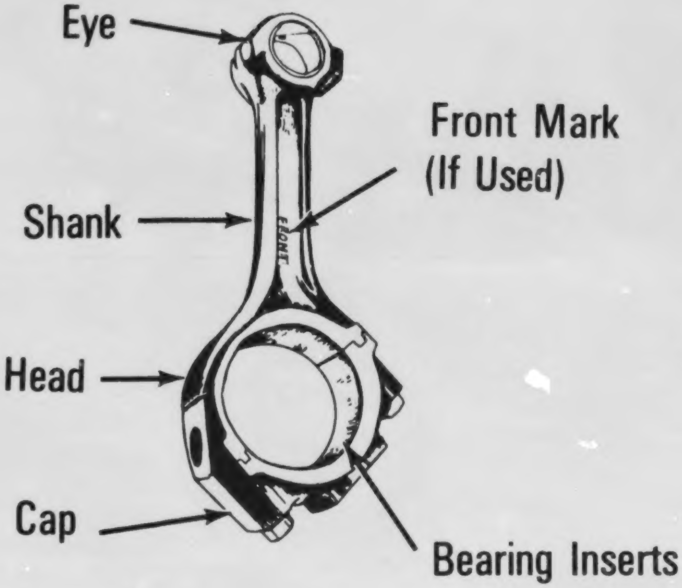
Fastened to Rod



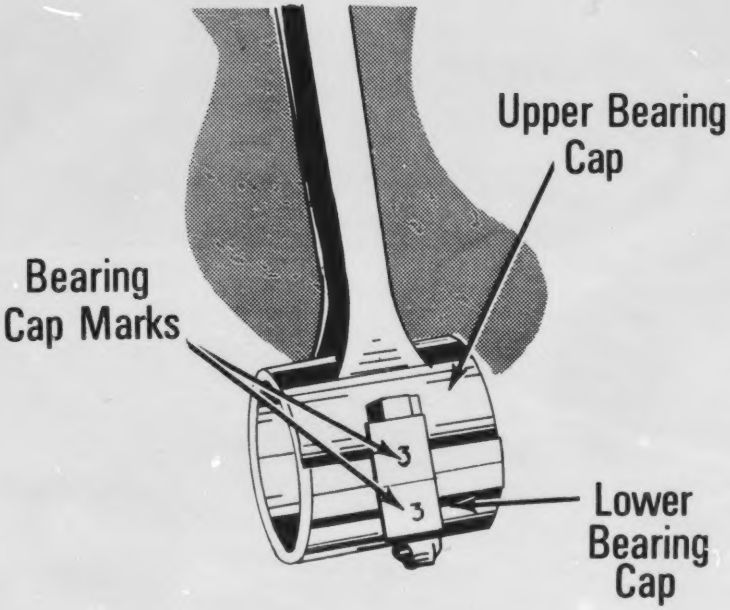
Full Floating Pin

Fastened by Spring Clips

Connecting Rod Markings


Eye
Front Mark
(If Used)
Shank
FRONT
Head
Cap
Bearing Inserts

Connecting Rod Angle Cut


Upper Bearing
Cap
Bearing
Cap Marks
3
3
Lower
Bearing
Cap

Connecting Rod Square Cut

TM 6

D:F - 79-C

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #1--REMOVE PISTON AND CONNECTING ROD ASSEMBLY

I. Tools and materials

   A. Basic hand tools

   B. Shop towels

   C. Drop light

   D. Bench vise

   E. Chemical cleaning solution

   F. Solvent to remove oil film

   G. Water spray supply

   H. Compressed air supply

   I. Safety glasses

   J. Appropriate service manual

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Remove cylinder head assembly and secure liner as necessary

   B. Remove piston

      1. Remove oil level gauge and gauge tube

      2. Remove fuel drain lines and other parts as necessary

      3. Clean the carbon ridge from top of cylinder liner

      4. Remove oil pan

      5. Rotate the crankshaft clockwise as necessary to gain access to the connecting rod cap

      6. Remove the connecting rod cap and retaining bolts

         (NOTE: Mark rod and cap if not already marked.)

      7. Push the piston upward until the rings clear the cylinder liner

         (CAUTION: Protect the connecting rod journal.)

JOB SHEET #1

8. Lift the piston and connecting rod from the liner
9. Replace cap on rod after removal
10. Repeat above steps for remaining pistons

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #2--REMOVE PISTON RINGS AND PISTON FROM ROD

I. Tools and materials

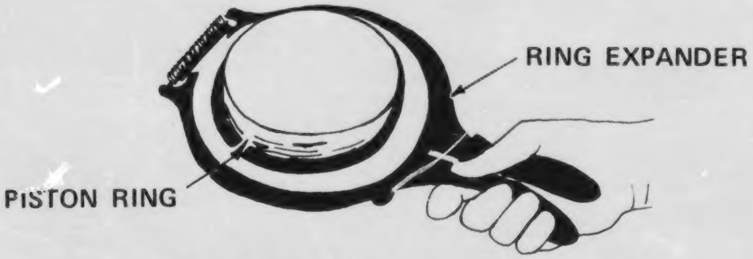
- A. Ring expander
- B. Basic hand tools
- C. Shop towels
- D. Snap ring pliers
- E. Safety glasses
- F. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Use a ring expander and remove all rings from piston (Figure 1)

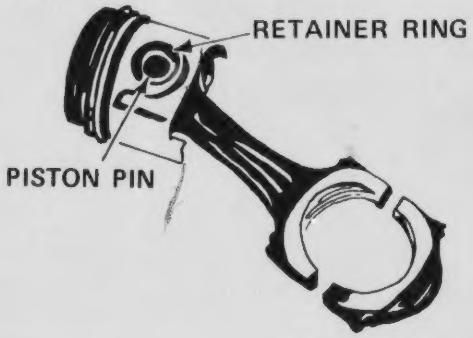
FIGURE 1



JOB SHEET #2

B. Remove retainer ring (snap ring) with snap ring pliers, and remove piston pin from the piston and connecting rod (Figure 2)

FIGURE 2



(NOTE: On some semi-floating piston pins it will require pressing the pin out of the piston or the rod.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #3--CLEAN PISTONS

I. Tools and materials

- A. Basic hand tools
- B. Shop towels
- C. Solvent to remove oil film
- D. Chemical cleaning solution
- E. Safety glasses
- F. Glass bead machine (if used)
- G. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: To clean pistons, use one of the following methods.)

- A. Use a chemical solution to soak pistons
    1. Use a solvent to remove oil film from pistons
    2. Mix the cleaner solution and heat as recommended
    3. Soak the pistons in the cleaning solution for specified time
    4. Soak for a second period if needed and scrape lightly if needed

       (CAUTION: Never use a wire brush.)
    5. Drain and spray rinse with water and air

       (NOTE: Be sure the piston ring grooves are thoroughly cleaned.)
- B. Use glass beads to clean pistons
    1. Wash pistons in solvent to remove grease and oil

       (CAUTION: Use a stiff brush, not a wire brush.)
    2. Spray the pistons dry using compressed air
    3. Clean the pistons in the glass bead cleaning machine using proper size beads and correct pressure

JOB SHEET #3

4. Keep the blast moving

   (CAUTION: Do not hold bead blast on one area too long or metal may be eroded.)

5. Hold the nozzle away from the surface; distance will vary depending on recommended pressure

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #4--INSPECT AND MEASURE PISTONS FOR WEAR

I. Tools and materials

   A. Basic hand tools

   B. Feeler gauges

   C. Outside micrometers

   D. Shop towels

   E. Safety glasses

   F. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

   A. Inspect pistons

      1. Examine for score marks, damaged ring grooves, or sign of overheating

      2. Ispect piston for cracks in head and skirt area and for bent or broken lands

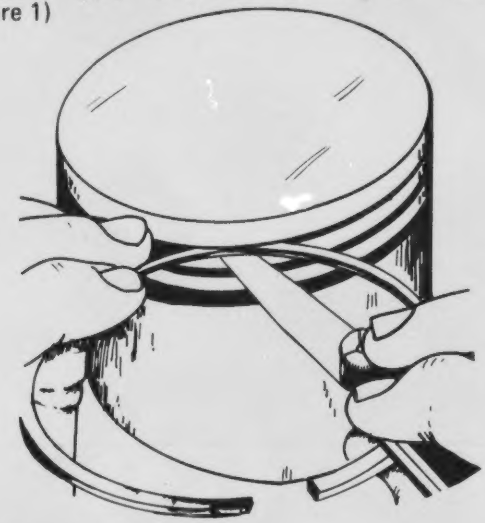
      (NOTE: Replace if damaged.)

   B. Measure ring grooves for wear

      1. Install a new ring in groove (Figure 1)

2. Insert feeler gauge between upper surface of new ring and the land to check clearance (Figure 1)

FIGURE 1



Measure Ring Clearance with a Feeler Gauge

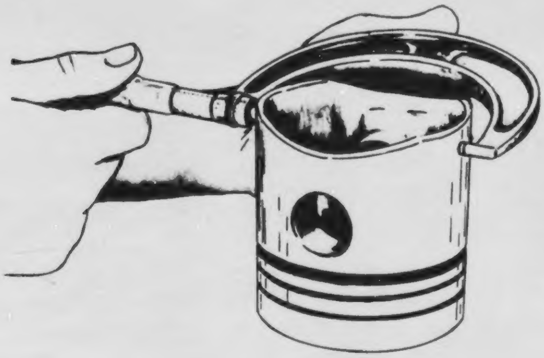
3. Check all ring grooves at several points

   (NOTE: Follow engine manufacturer's recommendation for wear limits.)

C. Measure piston for wear

1. Using outside micrometers, measure diameter of piston skirt at right angles to the piston pin bore (Figure 2)

FIGURE 2



Checking Piston Wear

JOB SHEET #4

2. Take a reading at both top and bottom of skirt

3. Compare these measurements with new dimensions given in the engine technical manual

4. Note the difference which is piston wear

D. Measure piston to cylinder clearance

1. Measure the cylinder diameter at right angles to the crankshaft in the lower or least-worn area of the cylinder, using a cylinder dial gauge, an inside micrometer, or a telescope gauge with outside micrometer

2. Measure the diameter of the piston across the thrust faces with an outside micrometer (Figure 2)

(NOTE: The difference between these two measurements is the piston clearance. Replace pistons if their clearance exceeds manufacturer's specifications.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #5--INSTALL RINGS AND ASSEMBLE PISTON TO ROD

I. Tools and materials

- A. Ring expander
- B. Basic hand tools
- C. Shop towels
- D. Snap ring pliers
- E. Safety glasses
- F. Appropriate service manual

II. Procedure

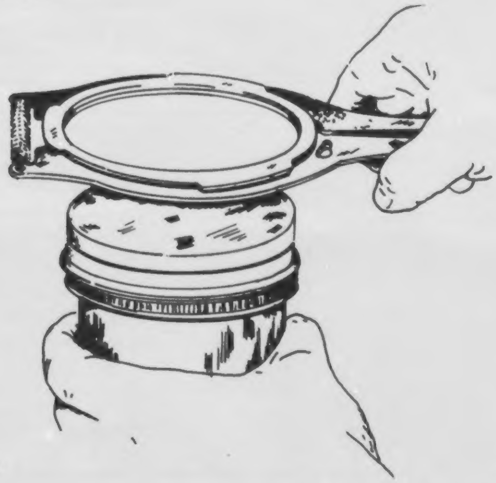
(CAUTION: Follow all shop safety procedures.)

A. Install rings

(NOTE: Refer to engine technical manual or ring manufacturer for directions on installing different ring types.)

1. Using ring expander, install oil control ring (Figure 1)

FIGURE 1



Installing Piston Rings Using a Ring Expander

JOB SHEET #5

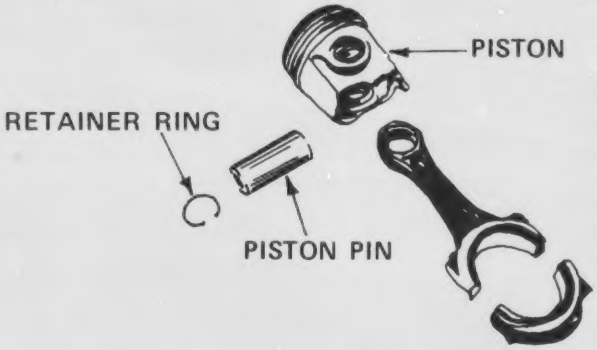
2. Using ring expander, install compression rings top side up
3. Stagger the ring ends according to manufacturer's recommendations

   (CAUTION: Do not twist, expand, or stretch rings too much.)

B. Install piston onto rod

1. Put piston in position on the connecting rod
2. Put clean oil on piston pin and install the piston pin (Figure 2)

   FIGURE 2



3. Install retainer rings

   (NOTE: Make sure the retainer rings are in the grooves of the piston.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #6--INSPECT PISTON PIN AND CONNECTING ROD BUSHING FOR SERVICEABILITY

I. Tools and materials

   A. Piston pin vise

   B. Straight edge

   C. Brass hammer

   D. Shop towels

   E. Compressed air supply

   F. Safety glasses

   G. Appropriate service manual

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Service piston pin

      1. Check pin for out-of-round or looseness

         a. Clamp pin in pin vise

         b. Rotate rod back and forth on pin

         c. Remove rod and examine shiny contact spots

         (NOTE: If pin contact does not show over entire surface, renew bushing.)

      2. Check bore for taper or bellmouthing (Figure 1)

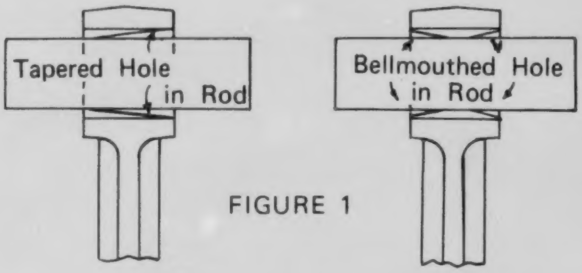


FIGURE 1

Bad Pin Fits in Connecting Rod

JOB SHEET #6

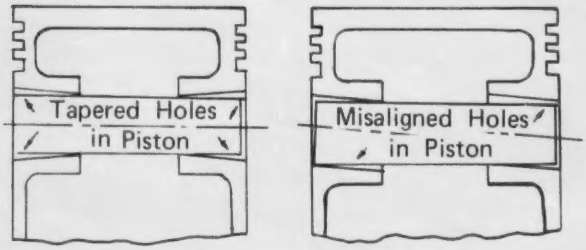
a. Insert pin from each end of the bushing

(NOTE: If pin is free on one end and tight on opposite end, the pin hole is tapered. If pin enters easily from either end but is tight in the center, the pin hole is bellmouthed.)

b. Renew bushing if pin hole is tapered or bellmouthed

3. Check for misalignment between the piston pin holes (Figure 2)

FIGURE 2



Bad Pin Fits in Piston Bosses

a. Push pin through pin hole toward second piston boss

(NOTE: If pin does not enter second boss without a click, misalignment has occurred.)

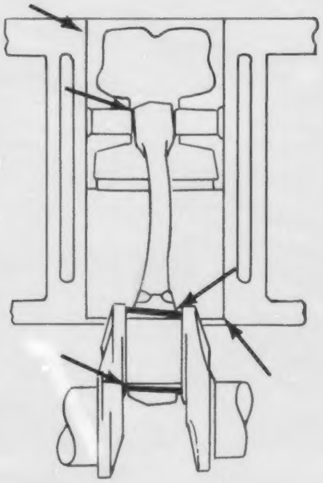
b. Install new bushing

JOB SHEET #6

B. Service connecting rods

1. Replace bent or twisted rod if wear points show on bearing in eye or cap (Figure 3)

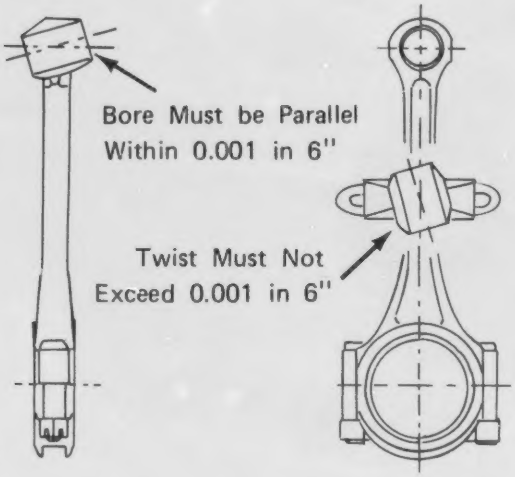
FIGURE 3



Wear Points from a Bent Rod

2. Replace rod if out of alignment to limit of 0.001 inch in six inches (Figure 4)

FIGURE 4


Bore Must be Parallel
Within 0.001 in 6"
Twist Must Not
Exceed 0.001 in 6"

Recommended Limits for Rod Alignment

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #7--INSPECT AND MEASURE CRANKSHAFT FOR WEAR

I. Tools and materials

   A. Outside micrometers

   B. Inside micrometers

   C. Rawhide mallet

   D. Torque wrench

   E. Oil pan gasket

   F. Shop towels

   G. Appropriate service manual

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Clean crankpins

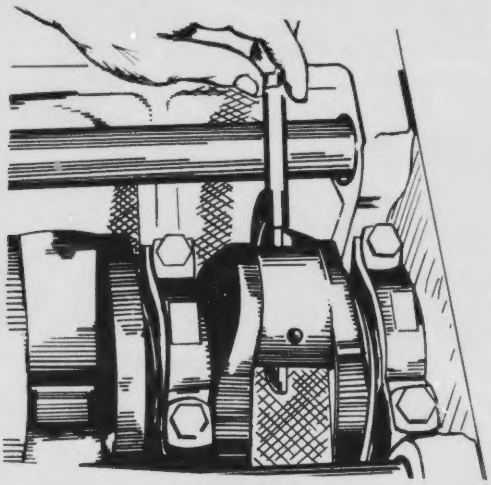
   B. Visually check for gouges, scratches, grooves, and scored surfaces

JOB SHEET #7

C. Measure crankshaft journals with outside micrometers and record on Charts 1 and 2 (Figure 1)

(NOTE: Write down minimum and maximum diameters; write down maximum shaft diameters and cylinder location.)

FIGURE 1



Measuring Crankshaft Rod Journals

D. Compare all measurements with manufacturer's standards

E. Make a decision as to the serviceability of the crankshaft

F. Assemble No. 1 cap and rod **without** bearings (insert shims if provided) and tighten bolts lightly

(NOTE: Tap cap lightly with rawhide mallet just before final tightening to the torque wrench setting recommended.)

D:F - 99-C

CHART 1

Engine Model # or size ________________

Main Bearing #1 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing # 1 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #2 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing #2 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #3 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing #3 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #4 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing #4 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #5 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing #5 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #6 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing #6 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #7 Taper

1.
2.
3.
4. Total taper ________________

Main Bearing #7 Out-of-Round

1.
2.
3. Total out-of-round ________________

CHART 2

Engine Model # or size ____________

Rod Bearing #1 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #1 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #2 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #2 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #3 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #3 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #4 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #4 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #5 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #5 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #6 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #6 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #7 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #7 Out-of-Round

1.
2.
3. Total out-of-round ____________

Rod Bearing #8 Taper

1.
2.
3.
4. Total taper ____________

Rod Bearing #8 Out-of-Round

1.
2.
3. Total out-of-round ____________

JOB SHEET #7

G. Check rod bore with inside micrometers or dial bore gauge for out-of-round (Figures 2 and 3)

FIGURE 2

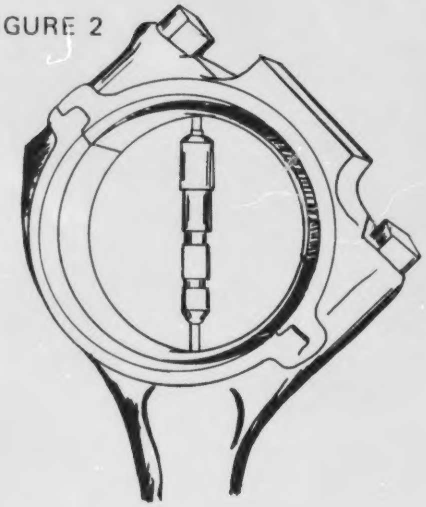
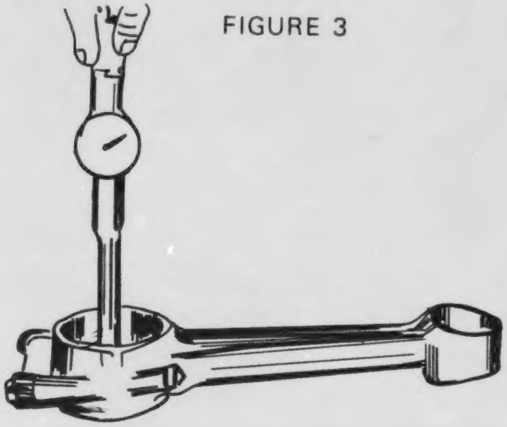


FIGURE 3



Checking Connecting Rod Crank Journal Bore

H. Remove caps from rods and clean all parts

I. Obtain new bearings to give the correct oil clearance with the maximum shaft sizes previously recorded in C above

(NOTE: Bearing clearance can also be measured with the crankshaft in place by using a plastigage. While this method will give the bearing clearance it will not tell whether the wear is on the bearing or on the crankshaft journal.)

J. Compare old and new bearings for correct oil grooves, holes, and lips

K. Insert correct lower half bearings into caps; make sure lip nests into slot

L. Place No. 1 rod assembly in No. 1 cylinder with marking in correct relation to camshaft; do the same with other rods

M. Insert upper half bearings into rod halves (now in engine); smear engine oil on bearing surfaces

N. Seat rod with bearing in place upon its crankpin and check rod marking with camshaft position

(CAUTION: See that the rod bolts do not touch crankpin.)

JOB SHEET #7

O. Assemble No. 1 cap and rod; do the same with rods No. 2 and No. 3, until complete

(NOTE: Markings must be on the same side, if used in original assembly. See Figures 5 and 6.)

FIGURE 5

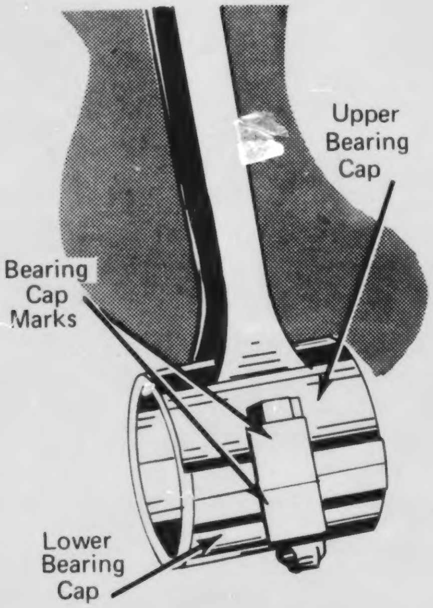
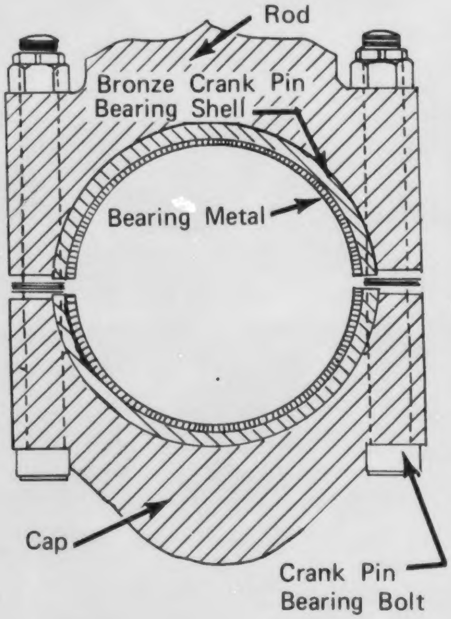

Upper
Bearing
Cap
Bearing
Cap
Marks
Lower
Bearing
Cap

FIGURE 6


Rod
Bronze Crank Pin
Bearing Shell
Bearing Metal
Cap
Crank Pin
Bearing Bolt

P. Take up on bolts lightly

(NOTE: Tap cap with mallet to find natural center.)

Q. Tighten with torque wrench to recommended setting

(NOTE: Rotate crankshaft by hand, after tightening each rod, to make sure it does not bind.)

R. Check complete installation in this order: markings, torque wrench readings, crankshaft tightness, and apply cotter pins or lock nuts

S. Attach oil leak detector, if available, as final check on both main and connecting rod bearings

T. Clean oil pan and oil pump screen thoroughly

U. Replace oil pan gaskets and assemble to engine

JOB SHEET #7

V. Fill with a good grade of oil of recommended viscosity to suit the season

W. Replace oil filter cartridge

X. Clean air cleaner

Y. Start engine and run just above idling speed until oil gauge registers normal pressure

(NOTE: Initial break-in of the engine bearings should be the same as breaking in a new engine.)

D:F - 105-C

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

NAME________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Outside part of piston below ring grooves

_____b. Area between ring grooves

_____c. Ties piston and rod together

_____d. Hole in piston which supports piston pin

_____e. Clearance between ends of piston rings

_____f. Combustion gases escaping to the crankcase

_____g. Overloading, causing unusual stress

_____h. Glowing or burning

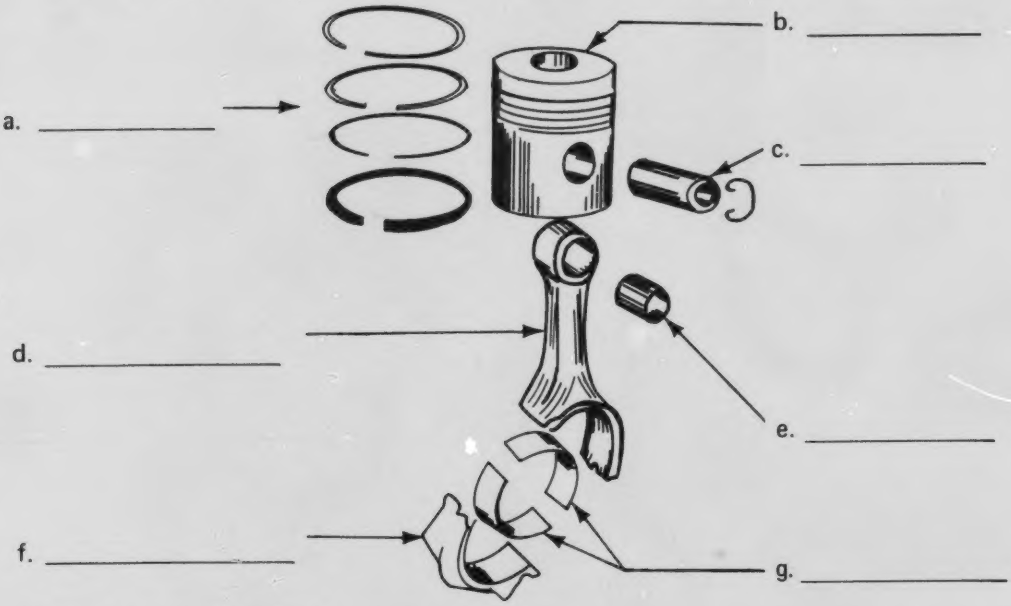
_____i. Upsetting the metal to decrease the inside diameter or increase the outside diameter

_____j. Piston pin that moves in both rod and piston

_____k. Soft, oil soluble, plastic thread

1. Piston pin
2. Piston pin boss
3. Piston land
4. Piston skirt
5. Ring joints
6. Blow-by
7. Plastigage
8. Full floating pin
9. Lugging
10. Incandescent
11. Knurling

2. Identify seven primary parts of a piston and connecting rod assembly.



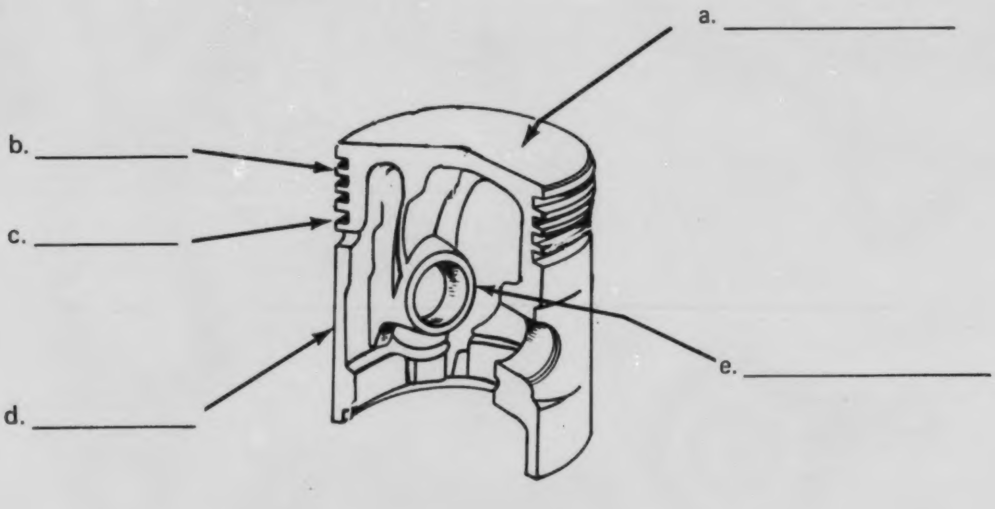
3. List three functions of the piston.

a. ____

b. ____

c. ____

4. Identify five main parts of a piston.



5. List three functions of piston rings.

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. Name the two types of piston rings.

   a. ______________________________

   b. ______________________________

7. Name three common types of ring joints.

   a. ______________________________

   b. ______________________________

   c. ______________________________

8. Select possible causes of high oil consumption and blow-by by placing an "X" in the appropriate blanks.

   ______ a. Piston rings installed wrong

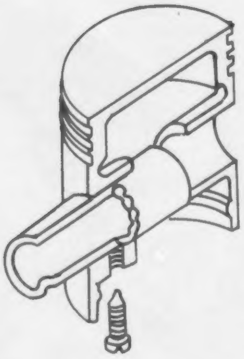
   ______ b. Plugged oil ring

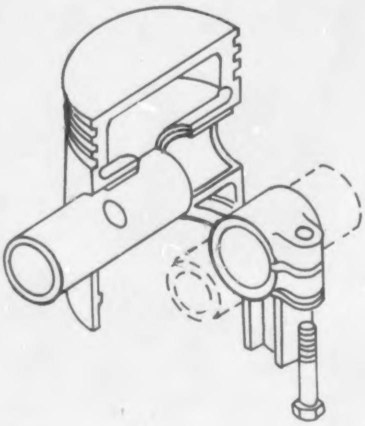
   ______ c. Stuck oil ring

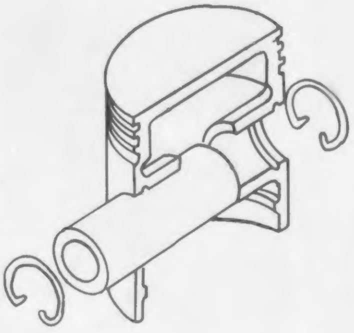
   ______ d. Burned exhaust valve

   ______ e. Overall wear in piston, rings, and cylinder

9. Identify three types of piston pins.







a. __________ b. __________ c. __________

10. Name two types of construction for the cap end of a connecting rod.

    a. ______________________________

    b. ______________________________

11. Complete the following list of statements concerning the reasons for markings on the connecting rod, piston, and bearing cap.

    a. On the piston--To install in same cylinder and on same side from which removed

    b. On the connecting rod--______________________________

    ____

    c. On the bearing cap--______________________________

    ____

12. Demonstrate the ability to:

    a. Remove piston and connecting rod assembly.

    b. Remove piston rings and piston from rod.

    c. Clean pistons.

    d. Inspect and measure pistons for wear.

    e. Install rings and assemble piston to rod.

    f. Inspect piston pin and connecting rod bushing for serviceability.

    g. Inspect and measure crankshaft for wear.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 1
   d. 2
   e. 5
   f. 6
   g. 9
   h. 10
   i. 11
   j. 8
   k. 7

2. a. Piston rings
   b. Piston
   c. Piston pin
   d. Connecting rod
   e. Piston pin bushing
   f. Connecting rod cap
   g. Bearing shells

3. a. Receives the force of combustion
   b. Transmits this force to the crankshaft
   c. Carries the piston rings which seal and wipe the cylinder

4. a. Head or crown
   b. Lands
   c. Ring grooves
   d. Skirt
   e. Piston pin boss

5. a. Forms a gas tight seal between piston and cylinder
   b. Helps cool the piston by transferring heat
   c. Controls lubrication between piston and cylinder wall

6. a. Compression rings
   b. Oil control rings

7. a. Step
   b. Angle
   c. Butt

8. a, b, c, e

9. a. Fixed
   b. Semi-floating
   c. Full floating

10. a. Square cut
    b. Angle cut

11. b. To install in same cylinder and on same side from which removed
    c. To install on same rod and on same side from which removed

12. Performance skills evaluated to the satisfaction of the instructor

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify primary parts of a camshaft and parts in a valve train. The student should also be able to remove, service, and install a camshaft. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with camshafts and gears with the correct definitions.
2. Name parts on some diesel engines that are actuated by the camshaft.
3. Identify three primary parts of a camshaft.
4. Identify four parts in a valve train.
5. Explain valve timing on a four-cycle engine.
6. Explain valve timing on a two-cycle engine.
7. Name four gears found in a typical gear train.
8. Name three gears which are marked in the gear train to insure correct valve timing.
9. Demonstrate the ability to:
    a. Remove a camshaft.
    b. Remove camshaft gear.
    c. Service a camshaft.
    d. Install a camshaft.
    e. Adjust valve clearance on a valve-in-head engine.
    f. Remove camshaft on a Detroit diesel engine.
    g. Inspect camshaft on a Detroit diesel engine.
    h. Install camshaft on a Detroit diesel engine.

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Have students draw different styles of gear set ups.

VIII. Have students make a list of different types of timing marks.

IX. Have students make a drawing of their engine timing.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Valve Clearance
    2. TM 2--Parts of a Camshaft
    3. TM 3--Valve Train
    4. TM 4--Gears in a Typical Gear Train
    5. TM 5--Timing Marks on Gear Train
    6. TM 6--Timing Chain

D. Job sheets

   1. Job Sheet #1--Remove a Camshaft
   2. Job Sheet #2--Remove Camshaft Gear
   3. Job Sheet #3--Service a Camshaft
   4. Job Sheet #4--Install a Camshaft
   5. Job Sheet #5--Adjust Valve Clearance on a Valve-in-Head Engine
   6. Job Sheet #6--Remove Camshaft on a Detroit Diesel Engine
   7. Job Sheet #7--Inspect Camshaft on a Detroit Diesel Engine
   8. Job Sheet #8--Install Camshaft on a Detroit Diesel Engine

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Engines*. 5th ed. Moline, Illinois: Deere and Company, 1980.

B. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, Inc., 1974.

C. *Engine Service Manual*. Peoria, Illinois: Caterpillar Tractor Company, 1972.

D. *Detroit Diesel Engines: Service Manual*. General Motors Corp., 1972.

E. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

INFORMATION SHEET

I. Terms and definitions

- A. Cam lobes--Eccentric on the camshaft which changes rotary motion to linear motion
- B. Backlash--Clearance between meshed gears
- C. Dual valves--Two valves operated by a single rocker arm
- D. Bridge or crosshead--Permits a single rocker arm to depress dual valves
- E. Valve clearance--Definite clearance between rocker arm and valve stem (Transparency 1)
- F. Cam followers--Drive the push rods to operate the valves

  (NOTE: Cam followers may also be called valve tappets.)
- G. Hydraulic valve lifters--Noiseless cam followers that automatically adjust for valve clearance

II. Parts actuated by the camshaft on some diesel engines

- A. Intake valve
- B. Exhaust valve
- C. Unit injector
- D. Air starting valves

III. Primary parts of a camshaft (Transparency 2)

- A. Drive gear
- B. Cams
- C. Bearing journal

IV. Parts in a valve train (Transparency 3)

- A. Valve
- B. Rocker arm

INFORMATION SHEET

   C. Push rod

   D. Cam follower

V. Valve timing on a four-cycle engine

   A. Camshaft turns at one-half the speed of crankshaft

   B. Each valve is opened and closed once during two revolutions of the crankshaft

VI. Valve timing on a two-cycle engine

   A. Camshaft turns at the same speed as crankshaft

   B. Exhaust valve is opened and closed once during one revolution of the crankshaft

      (NOTE: Intake port in cylinder liner is uncovered by the piston once during one revolution of the crankshaft.)

VII. Gears in a typical gear train (Transparency 4)

   A. Camshaft gear

   B. Crankshaft gear

   C. Idler gear

   D. Fuel injection pump and governor drive gear

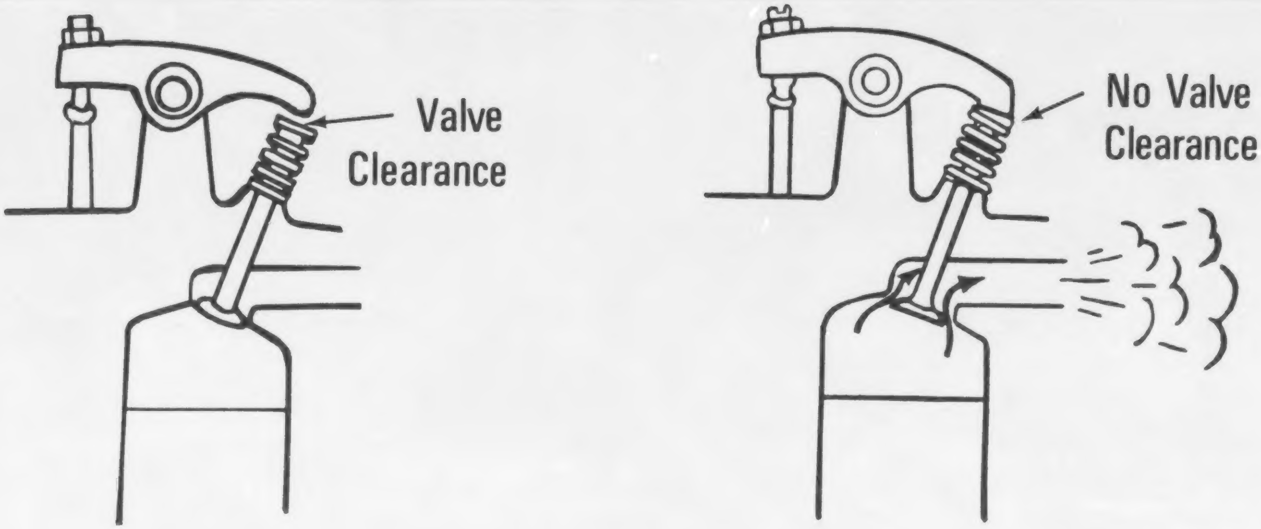
VIII. Gears marked to insure correct valve timing (Transparency 5)

   A. Crankshaft gear teeth

   B. Idler gear teeth

   C. Camshaft gear teeth

Valve Clearance

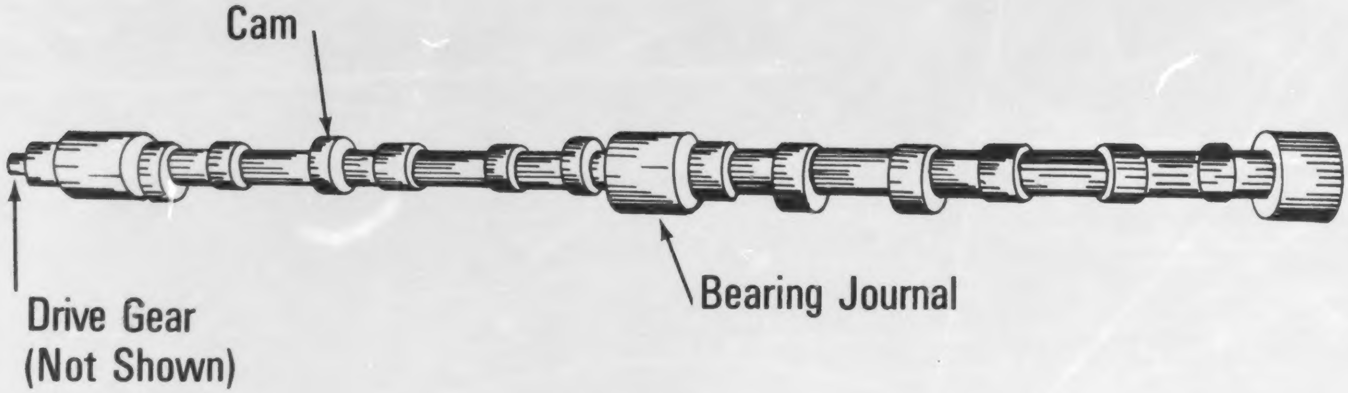

Valve
Clearance
No Valve
Clearance

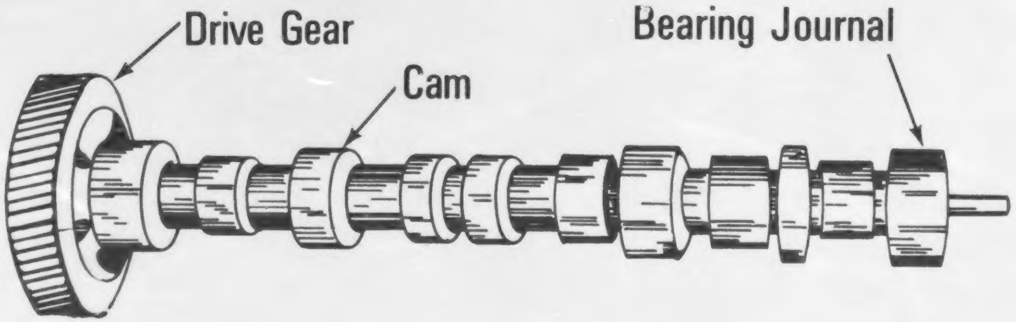
Valve Closes and Seals Gases in Cylinder

Valve Doesn't Seat. Power is Lost and Valve Overheats.

Problem of Too Little Valve Clearance

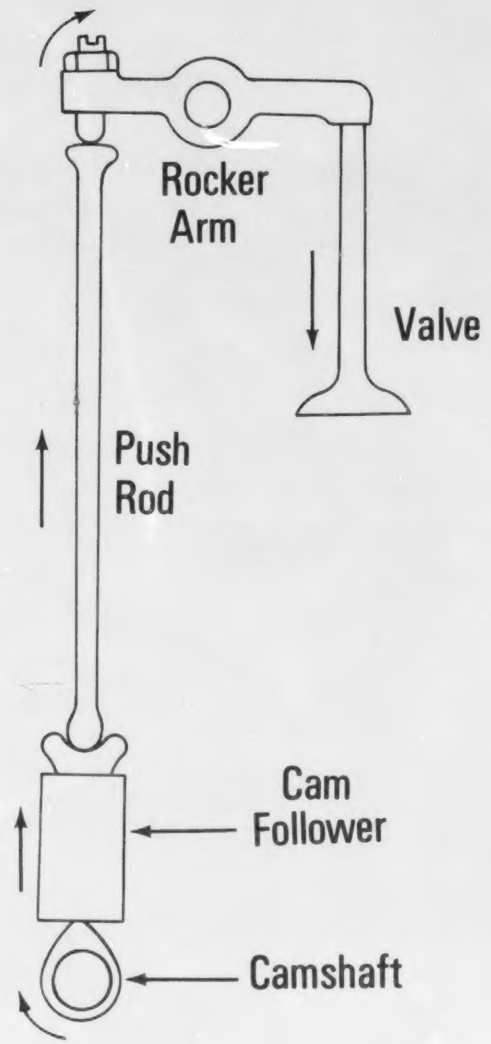
Parts of a Camshaft


Cam
Drive Gear (Not Shown)
Bearing Journal


Drive Gear
Cam
Bearing Journal

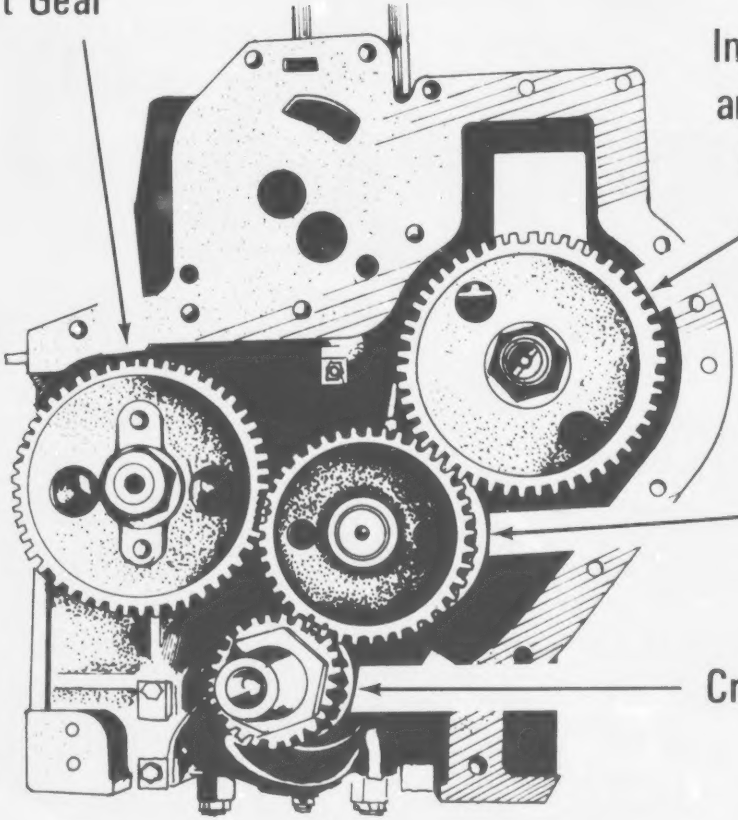
Valve Train

(Valve – in – Head Engine)

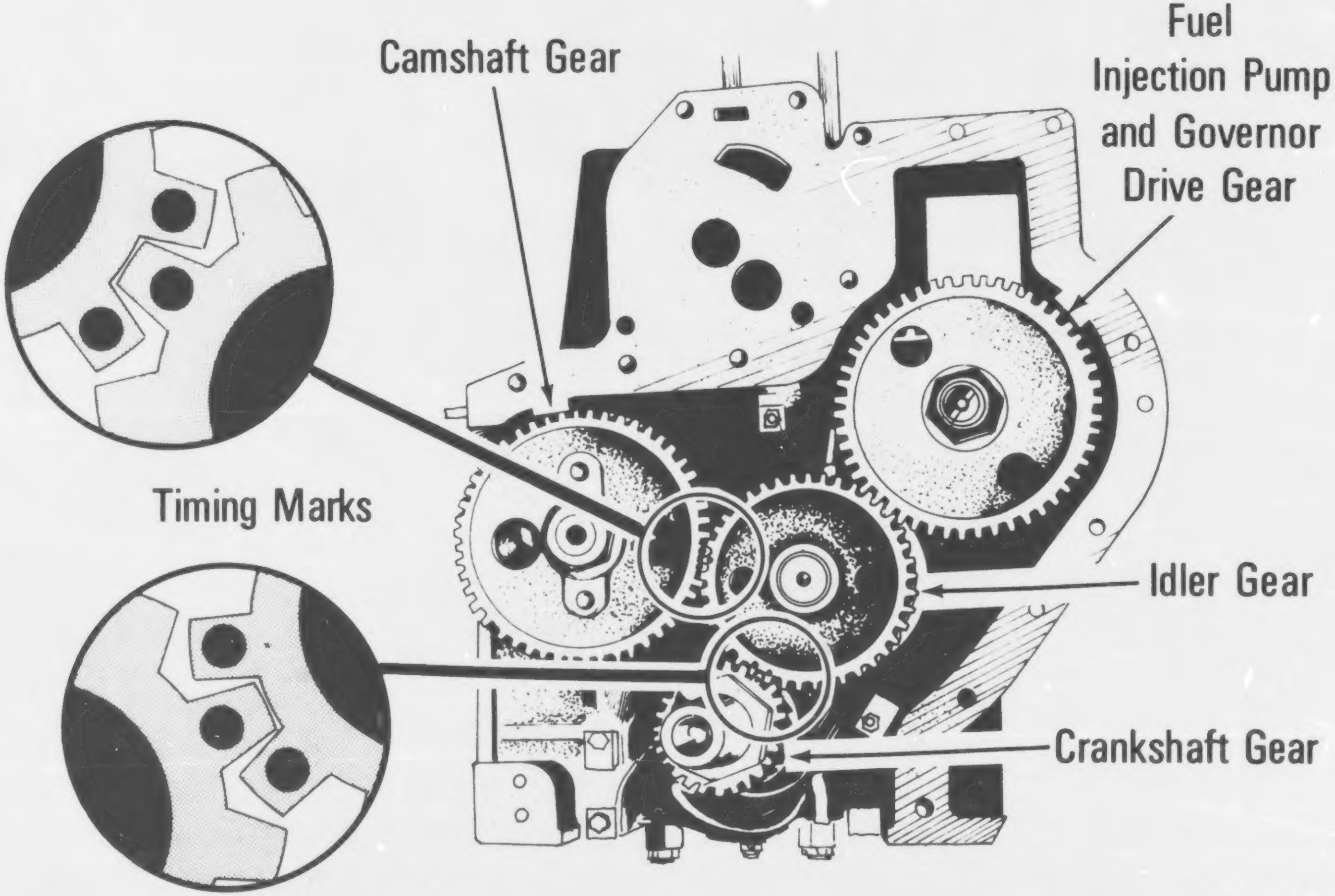

Rocker Arm
Valve
Push Rod
Cam Follower
Camshaft

552

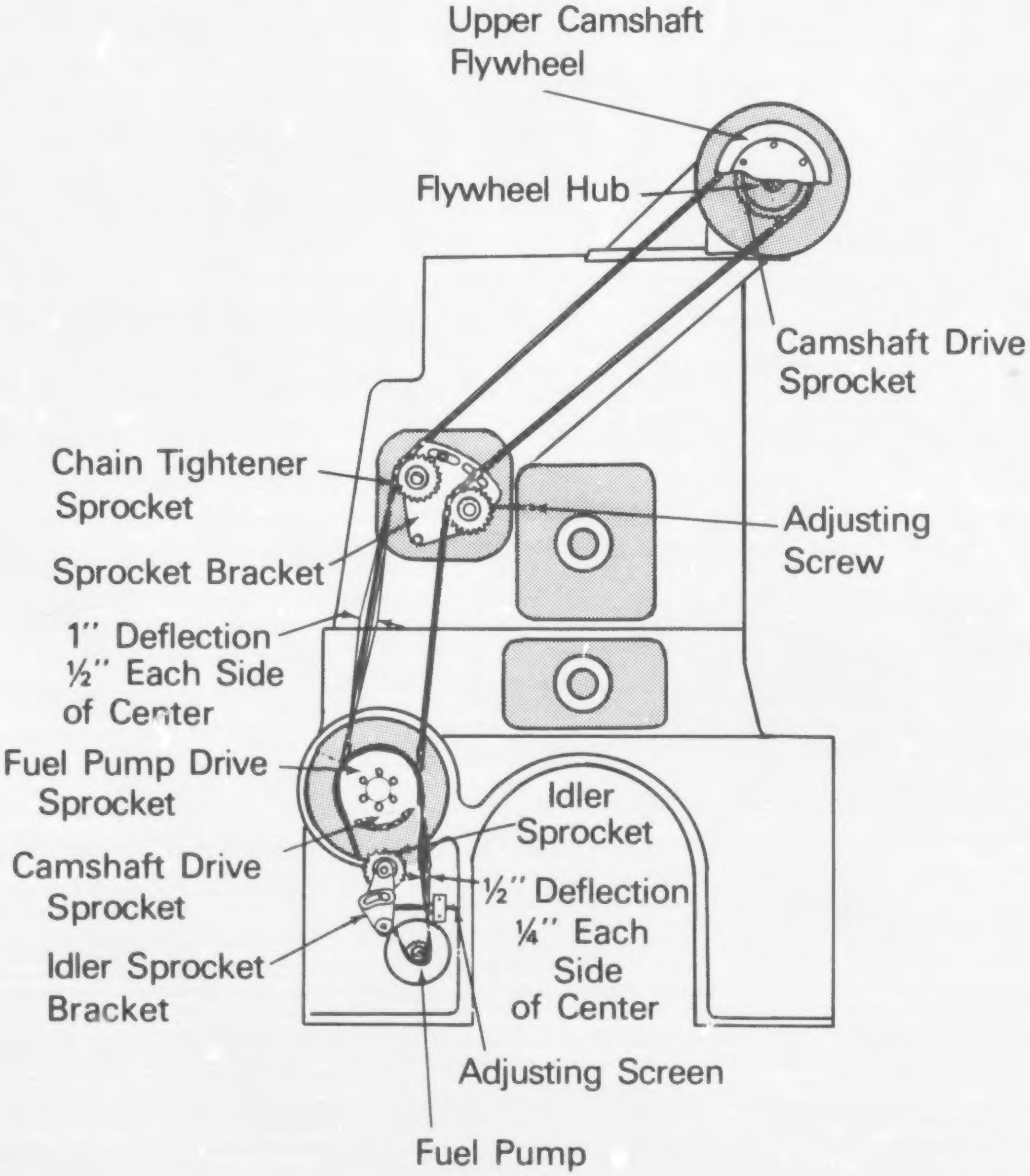
Gears in a Typical Gear Train


Camshaft Gear
Fuel Injection Pump and Governor Drive Gear
Timing Gears
Idler Gear
Crankshaft Gear

Timing Marks on Gear Train


Camshaft Gear
Fuel Injection Pump and Governor Drive Gear
Timing Marks
Idler Gear
Crankshaft Gear

Timing Chain


Upper Camshaft Flywheel
Flywheel Hub
Camshaft Drive Sprocket
Chain Tightener Sprocket
Adjusting Screw
Sprocket Bracket
1" Deflection ½" Each Side of Center
Fuel Pump Drive Sprocket
Idler Sprocket
Camshaft Drive Sprocket
½" Deflection ¼" Each Side of Center
Idler Sprocket Bracket
Adjusting Screen
Fuel Pump

557

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #1--REMOVE A CAMSHAFT

I. Tools and materials

A. Hand tools

B. Shop towels

C. Safety glasses

D. Appropriate service manual

II. Procedure

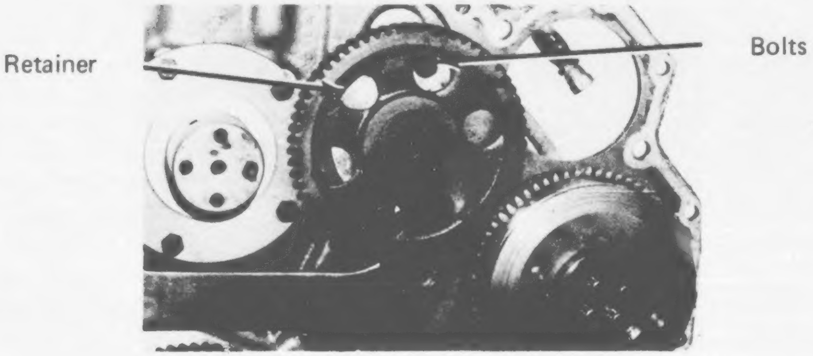
(CAUTION: Follow all shop safety procedures.)

(NOTE: It will be necessary to remove rocker arms, push rods, and cam followers before removing camshaft. It may be necessary to remove head in some instances so check manufacturer's service manual.)

A. Remove front timing cover

B. Remove bolts and retainer that holds camshaft to the cylinder block (Figure 1)

FIGURE 1



C. Carefully remove the camshaft assembly from the cylinder block

(CAUTION: Bring camshaft out of block slowly so as lobes on camshaft will not damage camshaft bearings.)

(NOTE: A good practice to follow before removing camshaft, is to align all timing marks to aid in installing camshaft.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #2--REMOVE CAMSHAFT GEAR

I. Tools and materials

A. Hand tools

B. Gear puller

C. Shop towels

D. Safety glasses

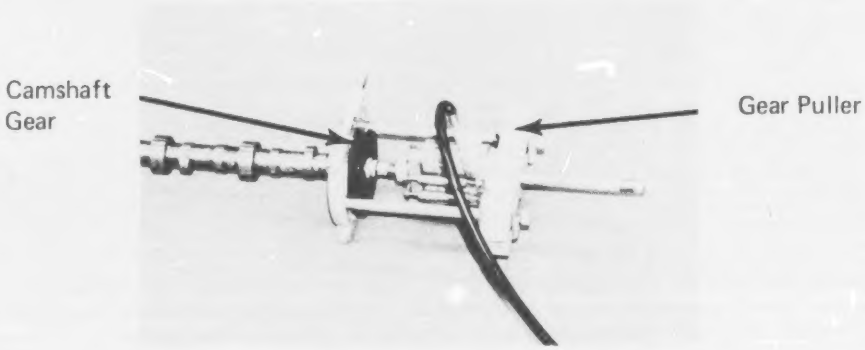
E. Appropricate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Remove camshaft gear from the camshaft with gear puller (Figure 1)

FIGURE 1



B. Remove gear puller from camshaft gear

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #3--SERVICE A CAMSHAFT

I. Tools and materials

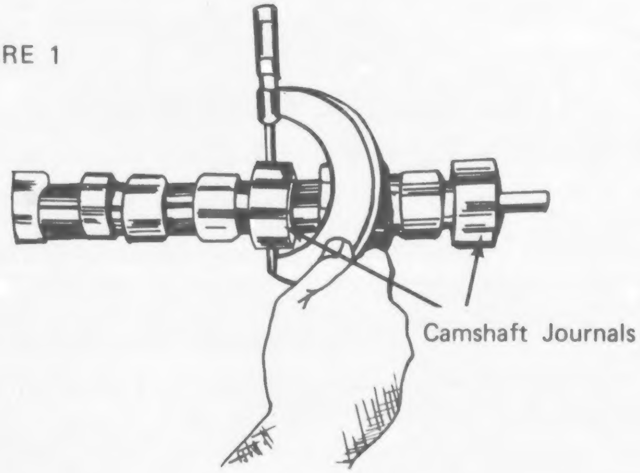
- A. Outside micrometer
- B. Inside micrometer or telescope gauge
- C. Shop towels
- D. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Inspect camshaft journals for signs of wear or out-of-round condition
- B. Measure the camshaft journals with an outside micrometer (Figure 1)

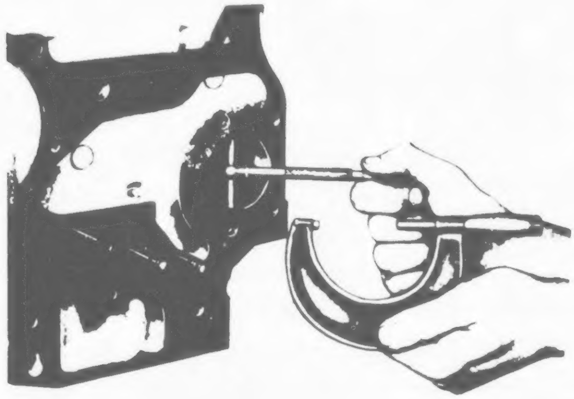
FIGURE 1



JOB SHEET #3

C. Measure the camshaft bores or bearings with a telescope gauge and outside micrometer (Figure 2)

FIGURE 2



Measuring Camshaft Bores

D. Compare the results with the specifications given by the manufacturer

E. Using micrometer, check each cam lobe for height

F. Compare intakes to other intakes

G. Compare exhausts to other exhausts

H. Replace camshaft if manufacturer's specifications are not met

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #4--INSTALL A CAMSHAFT

I. Tools and materials

   A. Hand tools

   B. Appropriate service manual

   C. Shop towels

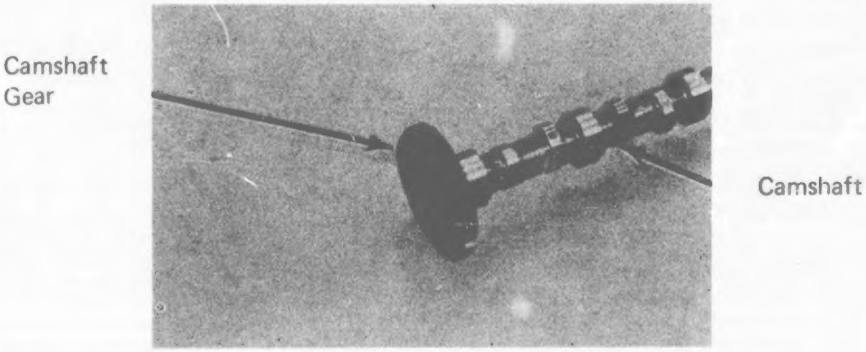
   D. Safety glasses

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Put the key in the camshaft in alignment with the groove (keyway in gear, and install on the camshaft (Figure 1)

FIGURE 1

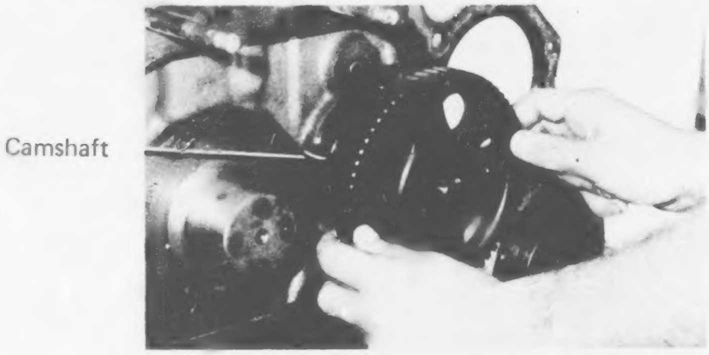


   B. Put clean engine oil on the lobes and journals of the camshaft

JOB SHEET #4

C. Carefully install the camshaft assembly in the cylinder block (Figure 2)

FIGURE 2



(CAUTION: Install camshaft very slowly as not to damage the camshaft bearings.)

D. Align all timing marks

E. Align the retainer that holds the camshaft in the cylinder block

F. Install bolts in retainer

G. Install front timing cover

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #5--ADJUST VALVE CLEARANCE ON A VALVE-IN-HEAD ENGINE

I. Tools and materials

   A. Correct size end wrench

   B. Screwdriver

   C. Feeler gauge

   D. Shop towels

   E. New valve cover gasket

   F. Appropriate service manual

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

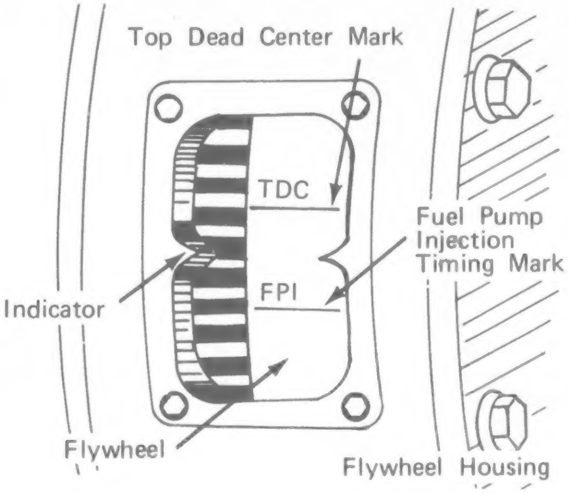
   A. Start engine and bring to normal operating temperature

      (NOTE: See manufacturer's recommendations for hot or cold adjustment.)

   B. Clean all dirt and oil from around valve cover and remove

   C. Turn engine over until piston No. 1 cylinder is at top dead center on the compression stroke (Figure 1)

      FIGURE 1

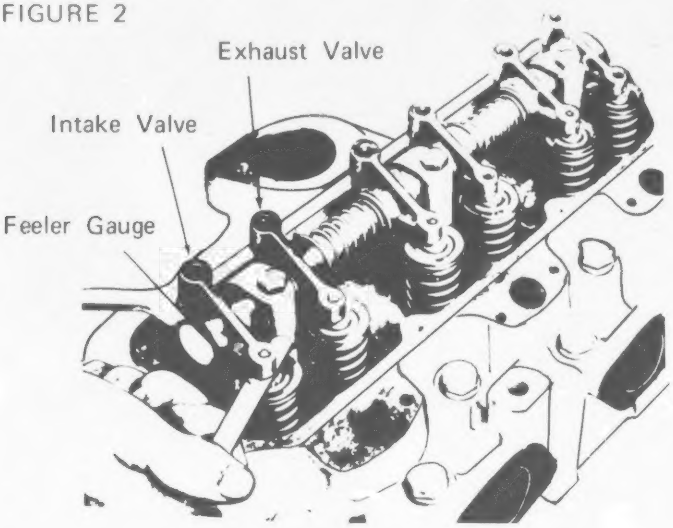

Top Dead Center Mark
TDC
Fuel Pump Injection Timing Mark
FPI
Indicator
Flywheel
Flywheel Housing

      (NOTE: During the compression stroke, both valves must be closed and the push rods must be loose.)

JOB SHEET #5

D. Using a feeler gauge, check the valve clearance (Figure 2)

FIGURE 2



(NOTE: Distinguish between the intake and the exhaust valve because the clearance may be different.)

E. Adjust to manufacturer's recommendation by loosening lock nut and turning valve adjusting screw up or down with screwdriver

F. Tighten lock nut with end wrench

G. Rotate the engine crankshaft in its firing order and adjust valve clearance when each piston reaches T.D.C. of its compression stroke

(NOTE: Two or three sets of valves may be set at a time with one rotation of the crankshaft.)

H. Install valve cover, using a new gasket

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #6--REMOVE CAMSHAFT ON A DETROIT DIESEL ENGINE

I. Tools and materials

A. Basic hand tools

B. 3/4" socket set

C. Block of wood

D. Shop towels

E. Safety glasses

F. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Drain the engine cooling system

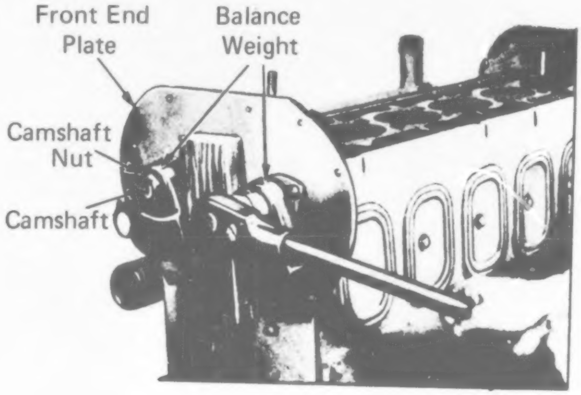
B. Remove the cylinder head

C. Remove the flywheel and flywheel housing

D. Remove the front balance weight cover

E. Place a wood block between the balance weights (Figure 1)

FIGURE 1



Loosening Nut on Camshaft or Balance Shaft

© General Motors Corporation

JOB SHEET #6

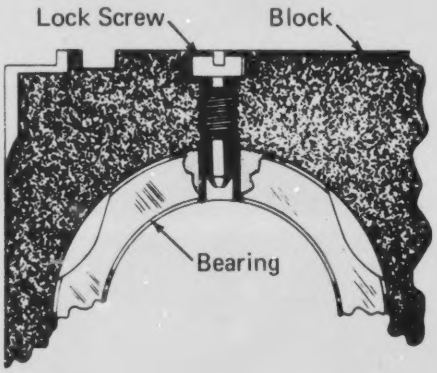
F. Remove the nut and lock washer from the balance weight end of each shaft

G. Remove the gear nut retaining plates, and remove the gear retaining nuts on the gear end of the camshaft and balance shaft

H. Remove the front balance weights

I. Remove the lock screws that secure the camshaft intermediate bearings (Figure 2)

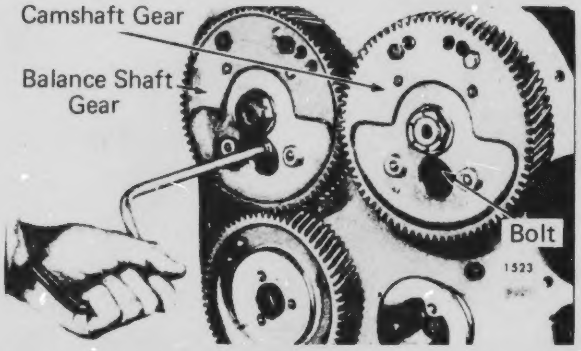
FIGURE 2


Lock Screw
Block
Bearing

© General Motors Corporation

J. Rotate the gears as required to reveal the end bearing retaining bolts, and remove bolts (Figure 3)

FIGURE 3


Camshaft Gear
Balance Shaft Gear
Bolt
1523

Removing or Installing Shaft Bearing Retainer Bolts

© General Motors Corporation

JOB SHEET #6

K. Withdraw the camshaft bearing and gear assembly and the balance shaft and gear from the rear end of the cylinder block

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #7--INSPECT CAMSHAFT ON A DETROIT DIESEL ENGINE

I. Tools and materials

- A. Feeler gauges
- B. Basic hand tools
- C. Shop towels
- D. Safety glasses
- E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Measure the flat on the injector rise side of cam lobes with a feeler gauge and a piece of square, hard material (Figure 1)

FIGURE 1

Checking Cam Lobe Wear

© General Motors Corporation

(NOTE: If the flats measure less then .003" in depth and there are no other defects, the camshaft is satisfactory for service.)

B. Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces; runout should not exceed .002"

JOB SHEET #7

C. Examine both faces of the camshaft rear end bearing and thrust washer

D. Examine the surfaces of each camshaft and camshaft gear which contact the thrust washers

(NOTE: Replace excessively worn or scored parts.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #8--INSTALL CAMSHAFT ON A DETROIT DIESEL ENGINE

I. Tools and materials

- A. Basic hand tools
- B. Shop towels
- C. Torque wrench
- D. Safety glasses
- E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Insert the camshaft into the cylinder block until the camshaft gear teeth almost engage the teeth of the mating gears

(CAUTION: Use care when installing the camshaft to avoid damaging the cam lobes.)

B. Align the timing marks on the mating gears and slide the camshaft gear in place

C. Rotate the camshaft gear, as required, to install the bolts through the hole in the gear web

D. Secure the camshaft rear end bearing to the cylinder block with the three bolts and lock washers, and tighten to specific torque

E. Install balance shaft and align timing marks

F. Apply grease to the steel face of each thrust washer, then place a thrust washer against the inner end of the camshaft and balance shaft front end bearing

G. Install the camshaft and balance shaft front end bearings with the bolts and lock washer, and tighten to specific torque

(NOTE: Install the front bearings with care to avoid damaging the thrust washers. **Do Not** hammer the bearing into the cylinder block.)

H. Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block, and tighten to specific torque

(NOTE: When the intermediate bearings are locked into position with the lockscrews, the bearings must have slight movement in the block bore.)

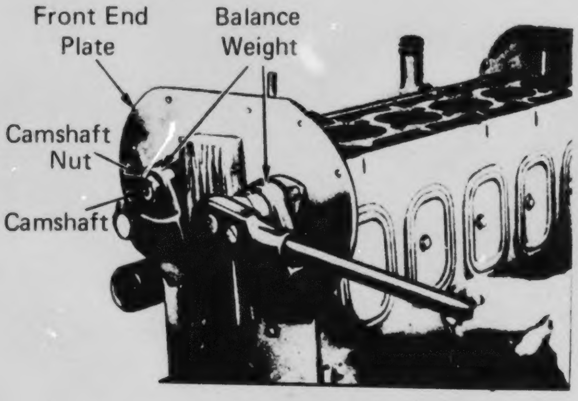
JOB SHEET #8

I. Install the front balance weights on the shafts

J. Place the internal tooth lock washers on the end of each shaft and start the nuts on both shafts

K. Use a wood block between the balance weights to prevent turning, and tighten nuts to specific torque (Figure 1)

FIGURE 1



Tighten Nut on Camshaft or Balance Shaft

© General Motors Corporation

L. Install the camshaft and balance shaft gear nut retainers with bolts and lock washers, and tighten to specific torque

M. Check the clearance between the thrust washer and the thrust shoulder of both the camshaft and balance shaft

N. Check the backlash between the mating gears

(NOTE: The specified backlash between new gears is .003" to .008" or a maximum of .010" between worn gears.)

O. Install the flywheel housing and other parts or assemblies that were removed from the engine

P. Refill the cooling system

D:F - 147-C

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

NAME______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Eccentric on the camshaft which changes rotary motion to linear motion

______b. Clearance between meshed gears

______c. Two valves operated by a single rocker arm

______d. Drive the push rods to operate the valves

______e. Noiseless cam followers that automatically adjust for valve clearance

______f. Definite clearance between rocker arm and valve stem

______g. Permits a single rocker arm to depress dual valves

1. Bridge or crosshead
2. Dual valves
3. Cam lobes
4. Backlash
5. Cam followers
6. Hydraulic valve lifters
7. Valve clearance

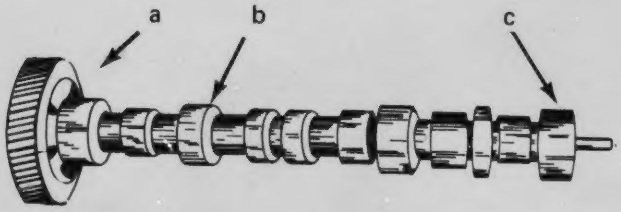
2. Name three parts on some diesel engines that are actuated by the camshaft.

a. ____

b. ____

c. ____

3. Identify three primary parts of a camshaft.

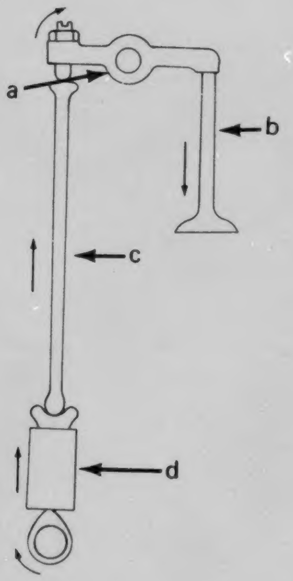


a. ____

b. ____

c. ____

4. Identify four parts in a valve train.



a. ______________________

b. ______________________

c. ______________________

d. ______________________

5. Explain valve timing on a four-cycle engine.

____

____

____

6. Explain valve timing on a two-cycle engine.

____

____

____

7. Name four gears found in a typical gear train.

a. ____

b. ____

c. ____

d. ____

8. Name three gears which are marked in the gear train to insure correct valve timing.

   a. ______________________________

   b. ______________________________

   c. ______________________________

9. Demonstrate the ability to:

   a. Remove a camshaft.

   b. Remove camshaft gear.

   c. Service a camshaft.

   d. Install a camshaft.

   e. Adjust valve clearance on a valve-in-head engine.

   f. Remove camshaft on a Detroit diesel engine

   g. Inspect camshaft on a Detroit diesel engine.

   h. Install camshaft on a Detroit diesel engine.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 2
   d. 5
   e. 6
   f. 7
   g. 1

2. Any three of the following:

   a. Intake valve
   b. Exhaust valve
   c. Unit injector
   d. Air starting valves

3. a. Drive gear
   b. Cams
   c. Bearing journal

4. a. Rocker arm
   b. Valve
   c. Push rod
   d. Cam follower

5. Explanation should include:

   a. Camshaft turns at one-half the speed of crankshaft

   b. Each valve is opened and closed once during two revolutions of the crankshaft

6. Explanation should include:

   a. Camshaft turns at the same speed as crankshaft

   b. Exhaust valve is opened and closed once during one revolution of the crankshaft

7. a. Camshaft gear
   b. Crankshaft gear
   c. Idler gear
   d. Fuel injection pump and governor drive gear

8. a. Crankshaft gear teeth
   b. Idler gear teeth
   c. Camshaft gear teeth

9. Performance skills evaluated to the satisfaction of the instructor

FRAMES AND CYLINDER BLOCKS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the stationary parts of three typical frame designs. The student should also be able to remove, install, and inspect a cylinder liner. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match frame and cylinder block terms with the correct functions.
2. Name the stationary parts of three typical frame designs.
3. Complete a list of statements concerning the purpose of through-bolts on an A-frame design engine.
4. Name three ways cylinder blocks may be constructed in regard to the cylinder proper.
5. Name two advantages a removable liner has over the integral cylinder bore.
6. Match the types of liners with statements on wet and dry liners.
7. Demonstrate the ability to:
    a. Remove a cylinder liner.
    b. Install and inspect a cylinder liner.

FRAMES AND CYLINDER BLOCKS
UNIT IV

SUGGESTED ACTIVITIES

- I. Provide student with objective sheet.
- II. Provide student with information and job sheets.
- III. Make transparencies.
- IV. Discuss unit and specific objectives.
- V. Discuss information sheet.
- VI. Demonstrate and discuss the procedures outlined in the job sheets.
- VII. Have students list the different types of liners.
- VIII. Have students visit different shops to see the block designs.
- IX. Show film on block cleaning.
- X. Give test.

INSTRUCTIONAL MATERIALS

- I. Included in this unit:
  - A. Objective sheet
  - B. Information sheet
  - C. Transparency masters
    1. TM 1–Engine Frames
    2. TM 2–Cylinder Liners
    3. TM 3--Cylinder Block and Cylinder Liner
  - D. Job sheets
    1. Job Sheet #1--Remove a Cylinder Liner
    2. Job Sheet #2–Install and Inspect a Cylinder Liner
  - E. Test
  - F. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. 3rd ed. Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines*. Moline, Illinois: Deere and Company, 1972.

C. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, Inc. 1974.

D. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc. 1982.

FRAMES AND CYLINDER BLOCKS
UNIT IV

INFORMATION SHEET

I. Frame and cylinder block terms and functions

   A. Frame--Stationary part which supports engine and keeps moving parts in line

   B. A-frame--Center frame has shape like an "A" and supports cylinder blocks

   C. Bed plate--Supports main bearings

   D. Center frame--Carries cylinder liners

   E. Through-bolts–Ties the bed plate, center frame, and head together

   F. Integral cylinder--Cylinder and water jacket cast in one piece

   G. Cylinder liner–Inside surface of the cylinder

   H. Wet liner–Liner is inserted into cylinder casting to form water jacket

   I. Dry liner--Makes metal to metal contact with cylinder casting containing water jacket

II. Stationary parts of frame designs (Transparency 1)

   A. Two-piece frame

      1. Bed plate

      2. Center frame

      (NOTE: For stationary engines which rest on a substantial foundation, the two-piece construction is most widely used.)

   B. Three-piece frame

      1. Bed plate

      2. Center frame

      3. Cylinder block

INFORMATION SHEET

C. A-frame

  1. Bed plate

  2. Center frame

  (NOTE: Another frame design is the automotive type, in which the case bearings are underslung from the upper section and the lower section is a crank pan.)

III. A-frame design with through-bolts

  A. Bed plate supports frames

  B. Frames support cylinder block

  C. Cylinder block supports cylinder head

  D. Through-bolts tie A, B, and C together

IV. Cylinder block construction (Transparencies 2 and 3)

  A. Cylinder bore an integral part of block

  B. Cylinder bore with removable wet liner

  C. Cylinder bore with removable dry liner

V. Advantages of removable liners over integral cylinder bore

  A. Allows room for expansion lengthwise

  B. May be replaced separately when worn

VI. Wet and dry liners (Transparencies 2 and 3)

  A. Wet liners

    1. Provide better cooling of cylinder

    2. May be replaced separately when worn

  B. Dry liners

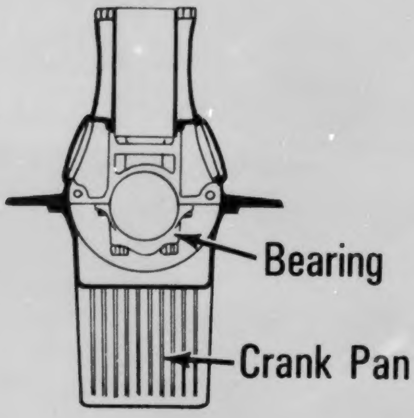
    1. Less trouble to replace

    2. Less expensive

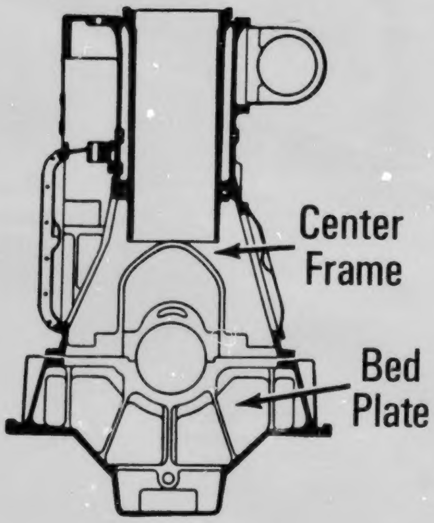
    3. Allow room for expansion lengthwise

    4. May be replaced separately when worn

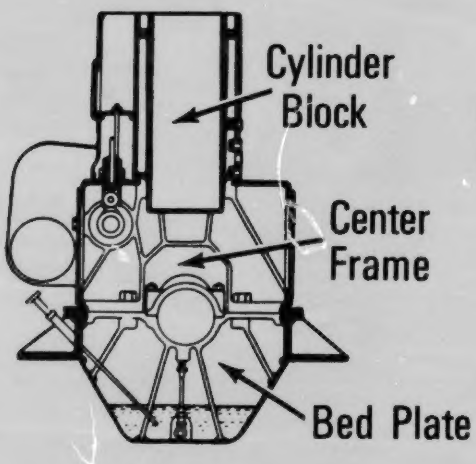
Engine Frames


Bearing
Crank Pan

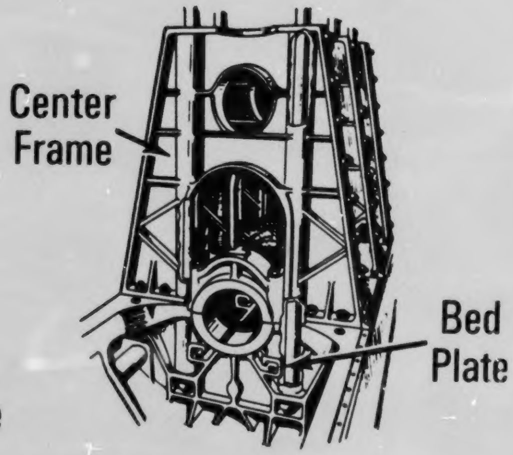
Automotive-Type Frame


Center Frame
Bed Plate

Two-Piece Frame

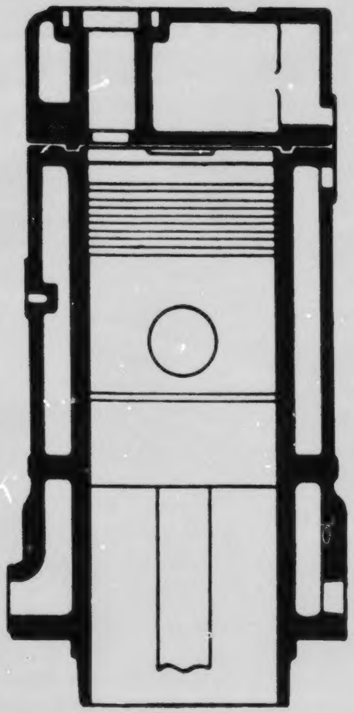

Cylinder Block
Center Frame
Bed Plate

Three-Piece Frame


Center Frame
Bed Plate

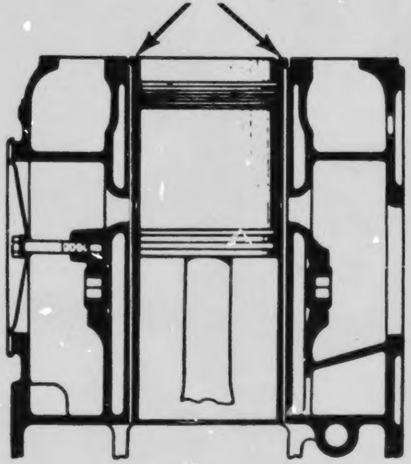
A-Frame Construction

Cylinder Liners



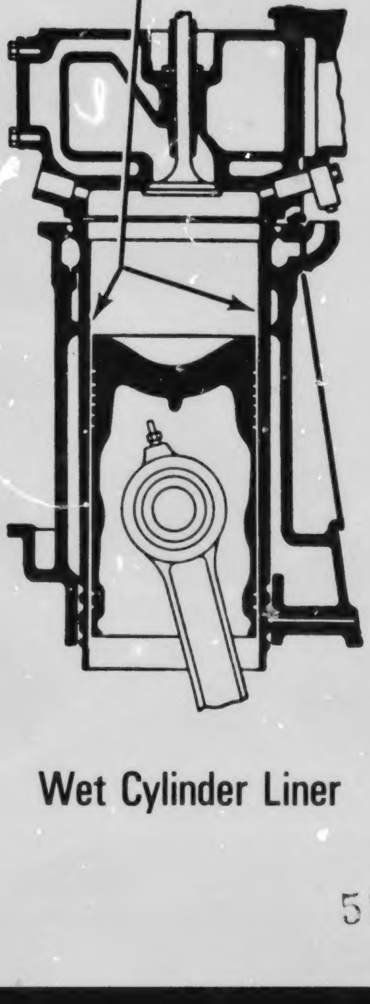
Cylinder Cast as One Piece

Liner is A Sleeve
Inside The Cylinder



Dry Cylinder Liner

Liner Forms
The Cylinder Itself



Wet Cylinder Liner

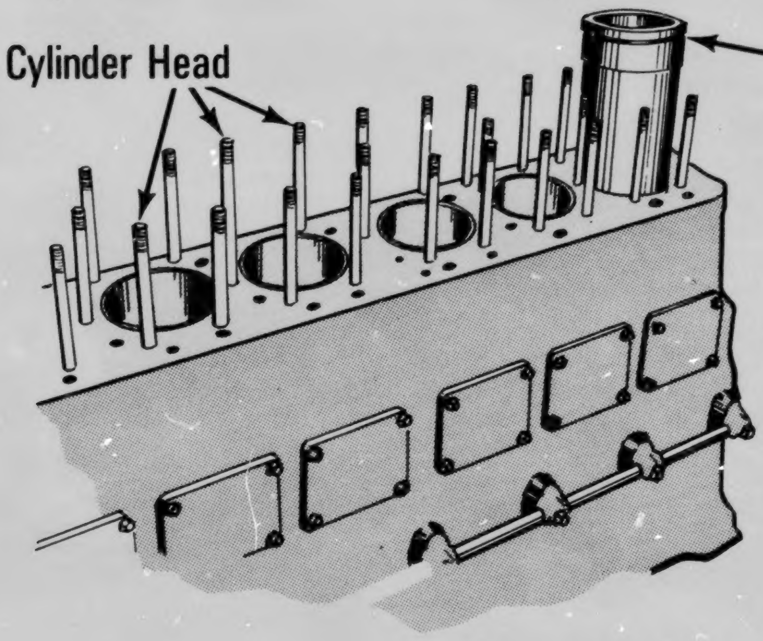
TM 2

583

D:F - 161-C

584

Cylinder Block and Cylinder Liner


Studs to Hold Cylinder Head
Wgt Type Cylinder Liner Partly Withdrawn

FRAMES AND CYLINDER BLOCKS
UNIT IV

JOB SHEET #1--REMOVE A CYLINDER LINER

I. Tools and materials

- A. Engine
- B. Appropriate service manual
- C. Screw-type liners pulling tool
- D. Basic hand tool set
- E. Cleaning agent
- F. Shop towels
- G. Emery cloth

II. Procedure

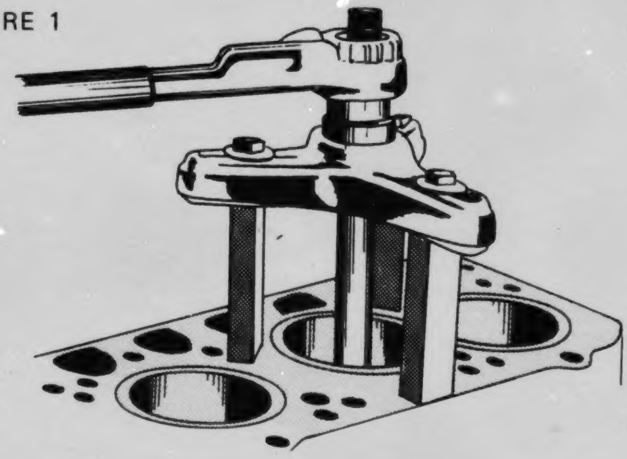
(CAUTION: Follow all shop safety procedures.)

(NOTE: Before removing liner check for out-of-round and taper.)

A. Remove cylinder liner

1. Note the identification marks on liner or valve recess location, and mark for future references
2. Use screw type liner pulling tool and remove liner (Figure 1)

FIGURE 1



3. Discard all used sealing rings

JOB SHEET #1

B. Clean cylinder block

C. Clean oil passages using a wire brush and air

D. Check cylinder block counterbore

E. Clean and inspect block bore area

1. Check for cracks along top of block and between cylinders
2. Check for burrs in counterbore
3. Check packing area for out-of-round and burrs
4. Check block surface for warpage.

FRAMES AND CYLINDER BLOCKS
UNIT IV

JOB SHEET #2--INSTALL AND INSPECT A CYLINDER LINER

I. Tools and materials

- A. Engine
- B. Appropriate service manual
- C. Clean shop towels
- D. Cylinder liner installation tool
- E. Gauge block
- F. Clean lubricating oil
- G. Micrometer (inside)

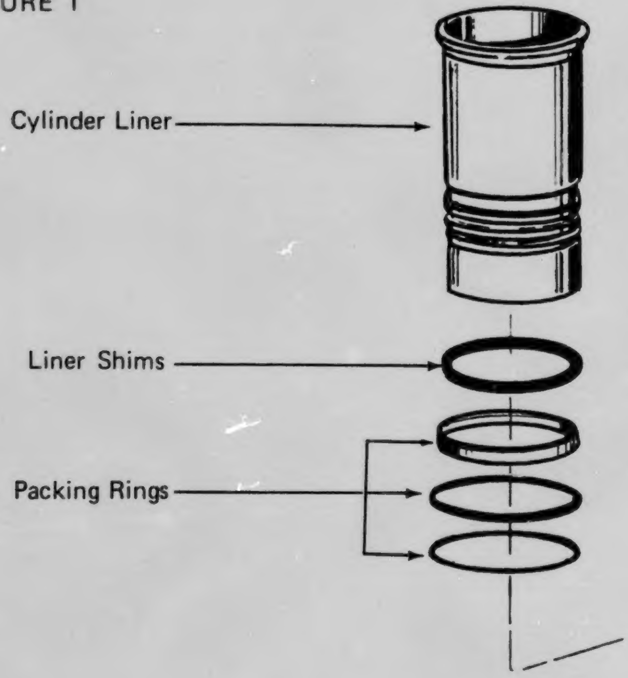
II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Install a cylinder liner

1. Lubricate new packing rings with grease
2. Install packing rings on cylinder liner according to manufacturer's specifications (Figure 1)

FIGURE 1



JOB SHEET #2

3. Place liner in engine bore and line up reference marks or valve recess location

   (NOTE: Placement should be done carefully so as not to damage packing rings.)

4. Use liner installation tool to finish installation

B. Inspect a cylinder liner

1. Use gauge block to check liner protrusion

2. Use inside micrometer to check packing area for out-of-roundness

   (NOTE: Refer to manufacturer's specifications and correct if necessary.)

D:F - 169-C

FRAMES AND CYLINDER BLOCKS
UNIT IV

NAME______________________

TEST

1. Match the terms on the right with the correct functions.

_____a. Stationary part which supports engine and keeps moving parts in line

_____b. Center frame has shape like an "A" and supports cylinder blocks

_____c. Supports main bearings

_____d. Carries cylinder liners

_____e. Ties the bed plate, center frame, and head together

_____f. Cylinder and water jacket cast in one piece

_____g. Inside surface of the cylinder

_____h. Liner is inserted into cylinder casting to form water jacket

_____i. Makes metal to metal contact with cylinder casting containing water jacket

1. Dry liner
2. A-frame
3. Cylinder liner
4. Integral cylinder
5. Wet liner
6. Center frame
7. Bed plate
8. Through-bolts
9. Frame

2. Name the stationary parts of three typical frame designs.

a. Two-piece frame

1) ______________________________

2) ______________________________

b. Three-piece frame

1) ______________________________

2) ______________________________

3) ______________________________

c. A-frame

1) ______________________________

2) ______________________________

3. Complete the following list of statements concerning the purpose of through-bolts on an A-frame design engine.

   a. Bed plate supports frames

   b. Frames support cylinder block

   c. ______________________________

   d. Through-bolts tie a, b, and c together

4. Name three ways cylinder blocks may be constructed in regard to the cylinder proper.

   a. ______________________________

   b. ______________________________

   c. ______________________________

5. Name two advantages a removable liner has over the integral cylinder bore.

   a. ______________________________

   b. ______________________________

6. Match the types of liners on the right with statements on wet and dry liners.

_____a. Less trouble to replace	1. Wet liners
_____b. Less expensive	2. Dry liners
_____c. Provide better cooling of cylinder	
_____d. May be replaced separately when worn	
_____e. Allows room for expansion lengthwise	

7. Demonstrate the ability to:

   a. Remove a cylinder liner.

   b. Install and inspect a cylinder liner.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

FRAMES AND CYLINDER BLOCKS
UNIT IV

ANSWERS TO TEST

1. a. 9
   b. 2
   c. 7
   d. 6
   e. 8
   f. 4
   g. 3
   h. 5
   i. 1

2. a. Two-piece frame

      1) Bed plate
      2) Center frame

   b. Three-piece frame

      1) Bed plate
      2) Center frame
      3) Cylinder block

   c. A-frame

      1) Bed plate
      2) Center frame

3. c. Cylinder block supports cylinder head

4. a. Cylinder bore an integral part of block
   b. Cylinder bore with removable wet liner
   c. Cylinder bore with removable dry liner

5. a. Allows room for expansion lengthwise
   b. May be replaced separately when worn

6. a. 2
   b. 2
   c. 1
   d. 1 and 2
   e. 2

7. Performance skills evaluated to the satisfaction of the instructor

CRANKSHAFTS AND BEARINGS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the parts of a crankshaft and list engine indications of bearing failure. The student should also be able to remove, inspect, and replace a crankshaft and bearings. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with crankshafts and bearings with the correct definitions.
2. Name four types of crankshaft construction.
3. Name six parts of a crankshaft.
4. List the effects of the arrangement of crankshaft throws.
5. Match the arrangement of crankcase throws with the number of cylinders in the engine.
6. Name three ways crankshaft balance is maintained.
7. Select true statements concerning the lubrication of the crankshaft and surrounding parts.
8. Distinguish between a bushing and a bearing.
9. Name three materials used in making bearing linings.
10. Name two types of bearing locks.
11. Define bearing crush.
12. State the purpose of oil grooves in the bearing.
13. Name two types of thrust bearings.
14. List three engine indications of bearing failure.
15. Match the percentages of bearing failure with the causes of bearing failure.
16. List functions of the flywheel.

17. Demonstrate the ability to:
    a. Remove a crankshaft.
    b. Inspect and measure a crankshaft and bearings.
    c. Install bearings and crankshaft.

CRANKSHAFTS AND BEARINGS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Display different types of thrust bearings.

VIII. Have students list different engine crankshaft designs.

IX. Have students make a list of specifications from a service manual.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Parts of the Crankshaft
    2. TM 2--Typical Two-Cycle Crankshaft
    3. TM 3--Arrangement of Crankshaft Throws
    4. TM 4--Counterweights, Vibration Damper, and Flywheel
    5. TM 5--Crankshaft Lubrication
    6. TM 6--Bushings and Bearings
    7. TM 7--Bearing Locks
    8. TM 8--Bearing Crush
    9. TM 9--Bearing Oil Grooves
    10. TM 10--Types of Thrust Bearings
    11. TM 11--Causes of Bearing Failure

D. Job sheets
  1. Job Sheet #1--Remove a Crankshaft
  2. Job Sheet #2--Inspect and Measure a Crankshaft and Bearings
  3. Job Sheet #3--Install Bearings and Crankshaft

E. Test

F. Answers to test

II. References:

A. *Engine Bearing Service Manual*, 8th ed. Detroit, Michigan: Federal-Mogul Corp.

B. *Engine Service Manual*. Peoria, Illinois: Caterpillar Tractor Company, 1972.

C. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, Inc., 1974.

D. *Fundamentals of Service: Engines*. 5th ed. Moline, Illinois: Deere and Company, 1980.

E. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

CRANKSHAFTS AND BEARINGS
UNIT V

INFORMATION SHEET

I. Terms and definitions (Transparency 1)

   A. Integral crankshaft--Made from a single billet of steel

   B. Journal--That part of a shaft or axle in contact with the bearing

   C. Crankshaft throw--Two crankshaft webs and one crankpin

   D. Crankshaft web--Forms the crank or throw between the crankpin and main journal

   E. Crankpin--Outer end of crank throw

   (NOTE: The crankpin is also called a connecting rod journal.)

   F. Vibration damper--Reduces torsional stress on the crankshaft caused by power strokes and the loads on the engine

   G. Statically balanced--Balanced while at rest

   H. Dynamically balanced--Balanced against the rotary outward force at high speed

   I. Bushing--Full round sleeve normally used to support light loads

   J. Bearing--Half round sleeve normally used to support heavy loads

   K. Bearing clearance--Measured difference between the inside diameter of the bearing and the outside diameter of the journal

   L. Short block--Engine block without cylinder head and external accessories

   M. Thrust bearing (not always end bearing)--Controls crankshaft end play

   Example: Flanged main bearing used to control crankshaft end play

   (NOTE: The thrust bearing affects end clearance.)

II. Types of crankshaft construction

   A. Integral--For small and medium size engines

   B. Sectional--For medium and large engines

   C. Semi-built-up--For large engines

   D. Built-up--For large engines

INFORMATION SHEET

III. Parts of a crankshaft (Transparency 1)

   A. Main bearing journals

   B. Connecting rod bearing journals

   C. Connecting rod counterweights

   D. Flywheel hub or flange

   E. Crankshaft gear

   F. Crankshaft throw

IV. Effects of the arrangement of crankshaft throws (Transparency 2)

   A. Balance the engine

   B. Smooth vibrations of turning shaft

   C. Equalize loads on the main bearings

   D. Determine the firing order of engine

V. Arrangement of crankshaft throws (Transparency 2)

   A. Two and four cylinder, throws 180° apart

   B. Three and six cylinder, throws 120° apart

   C. Eight cylinder, throws 90° apart

VI. Maintaining crankshaft balance (Transparency 3)

   A. Counterweights

   B. Vibration damper

   C. Flywheel

VII. Lubrication of crankshaft and surrounding parts (Transparency 4)

   A. Oil pressure through crankshaft lubricates rod and main bearing

   B. Excess oil from rod and main bearing lubricates surrounding parts

VIII. How bushings and bearings are used (Transparency 5)

   A. Bushing--A fully round sleeve used to support light loads and slow speeds

   B. Bearing--A half round sleeve used to support heavy loads and high speeds

INFORMATION SHEET

IX. Materials used in bearing linings

- A. Tin or lead base babbit
- B. Copper or aluminum alloys
- C. Multilayers of copper or aluminum alloys and silver combinations

X. Types of bearing locks (Transparency 6)

- A. Lip slot
- B. Dowel

XI. Bearing crush--Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened (Transparency 7)

XII. Purpose of bearing oil grooves--Bearing oil grooves carry the oil through to the connecting rod (Transparency 8)

XIII. Types of thrust bearings (Transparency 9)

- A. Separate thrust washers
- B. Thrust flanges on bearings

XIV. Engine indications of bearing failure

- A. Drop in lubricating oil pressure
- B. Excessive oil consumption
- C. Engine noise--Rhythmic knock

XV. Major causes of bearing failure (Transparency 10)

- A. Dirt--43 percent
- B. Lack of lubrication--16 percent
- C. Improper assembly--14 percent
- D. Misalignment--10 percent
- E. Overloading--9 percent
- F. Other--8 percent

INFORMATION SHEET

XVI. Functions of flywheel

A. Stores energy for momentum between power strokes

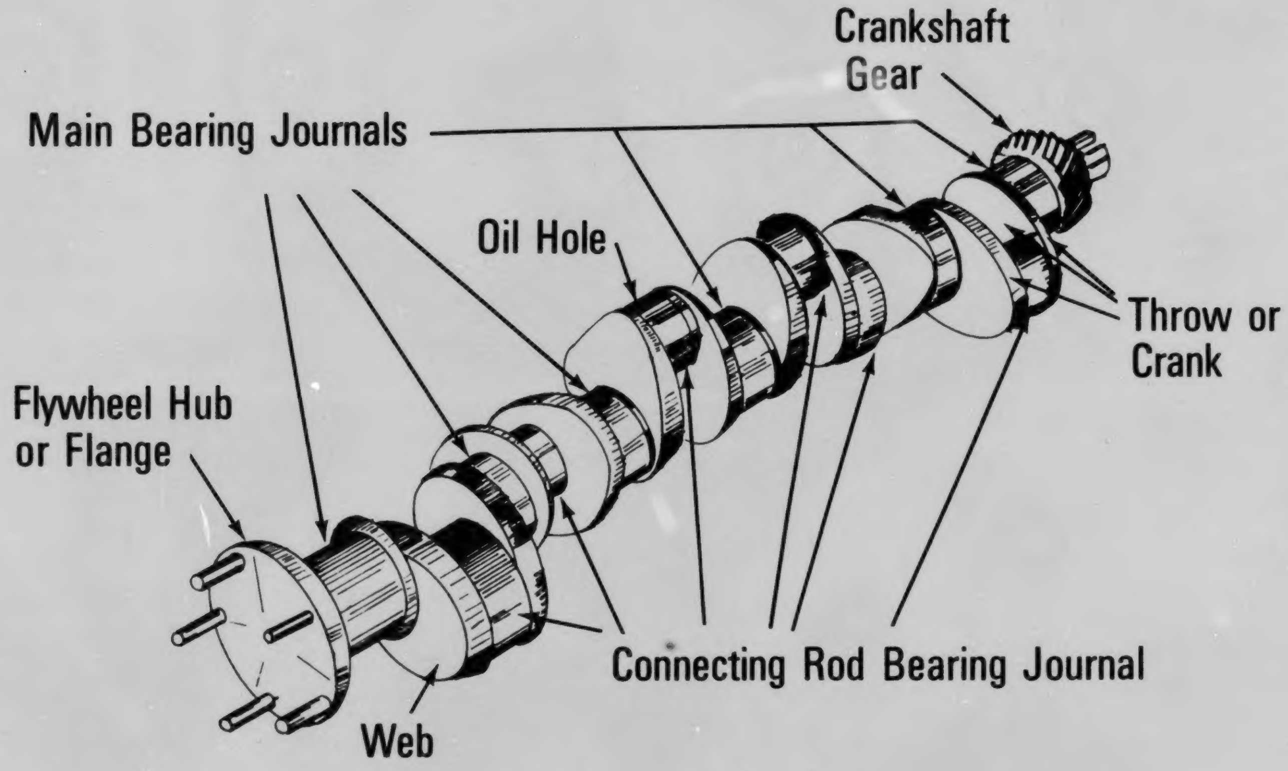
B. Smooths out speed of crankshaft

C. Transmits power to driven machine

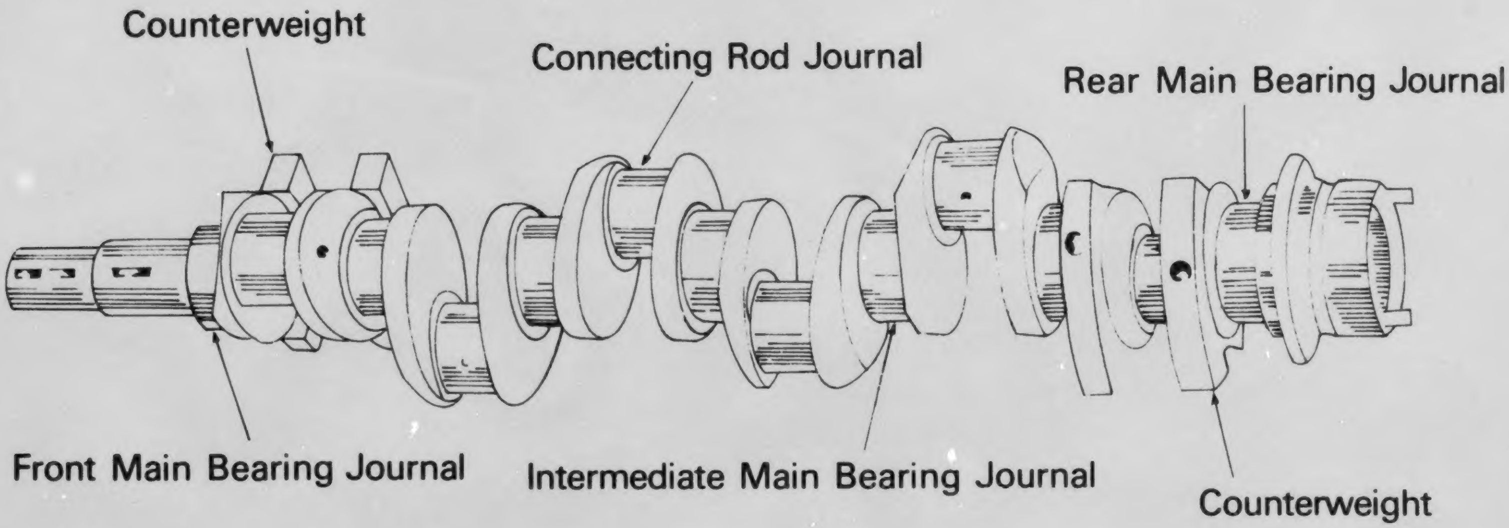
D. Provides a drive for starter via ring gear

E. Serves as a facing for engine clutch

Parts of the Crankshaft


Crankshaft Gear
Main Bearing Journals
Oil Hole
Throw or Crank
Flywheel Hub or Flange
Connecting Rod Bearing Journal
Web

Typical Two-Cycle Crankshaft


Counterweight
Connecting Rod Journal
Rear Main Bearing Journal
Front Main Bearing Journal
Intermediate Main Bearing Journal
Counterweight

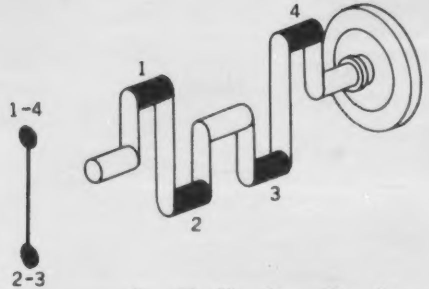
604

605

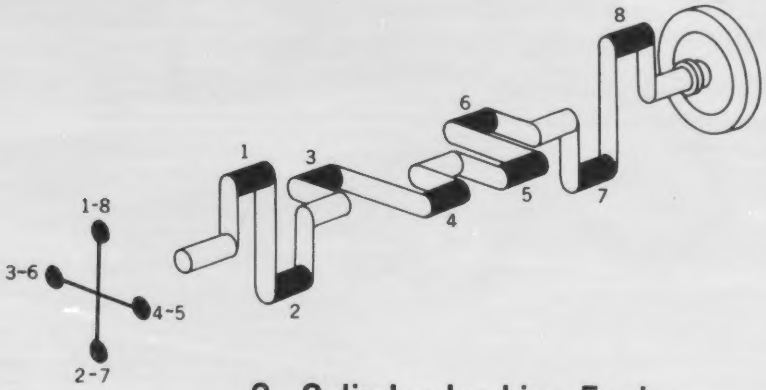
TM 2

D:F - 183-C

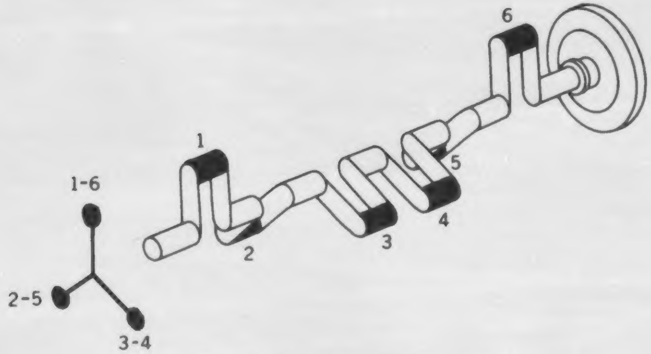
Arrangement of Crankshaft Throws



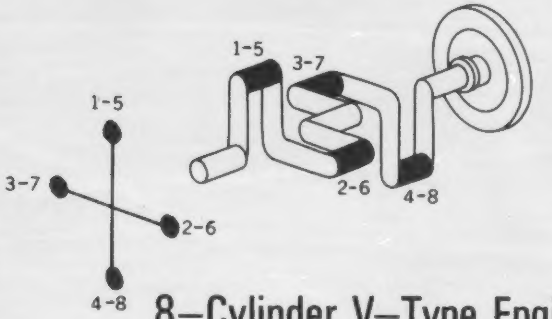
4–Cylinder Engine


1-8
3-6
4-5
2-7
1
2
3
4
5
6
7
8

8–Cylinder In–Line Engine

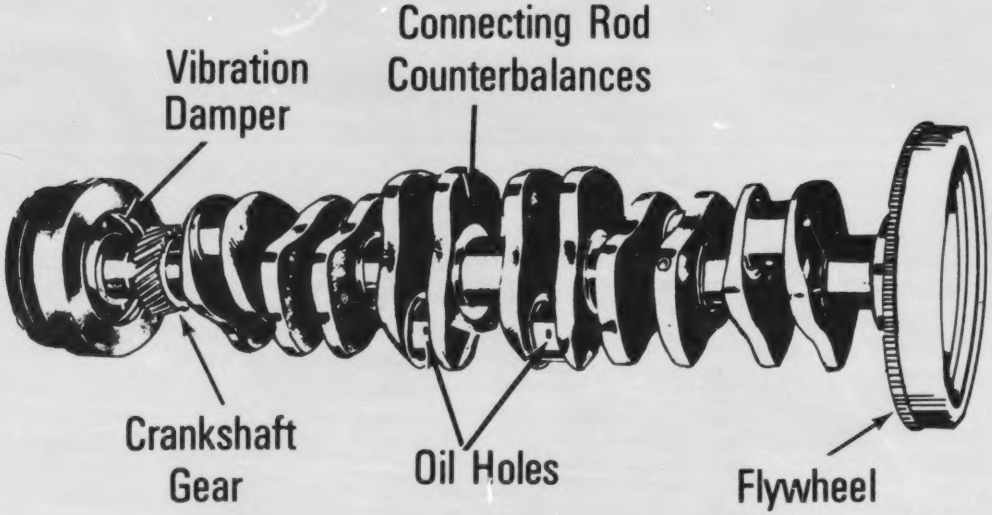

1-6
2-5
3-4
1
2
3
4
5
6

6–Cylinder Engine


1-5
3-7
2-6
4-8
1-5
3-7
2-6
4-8

8–Cylinder V–Type Engine

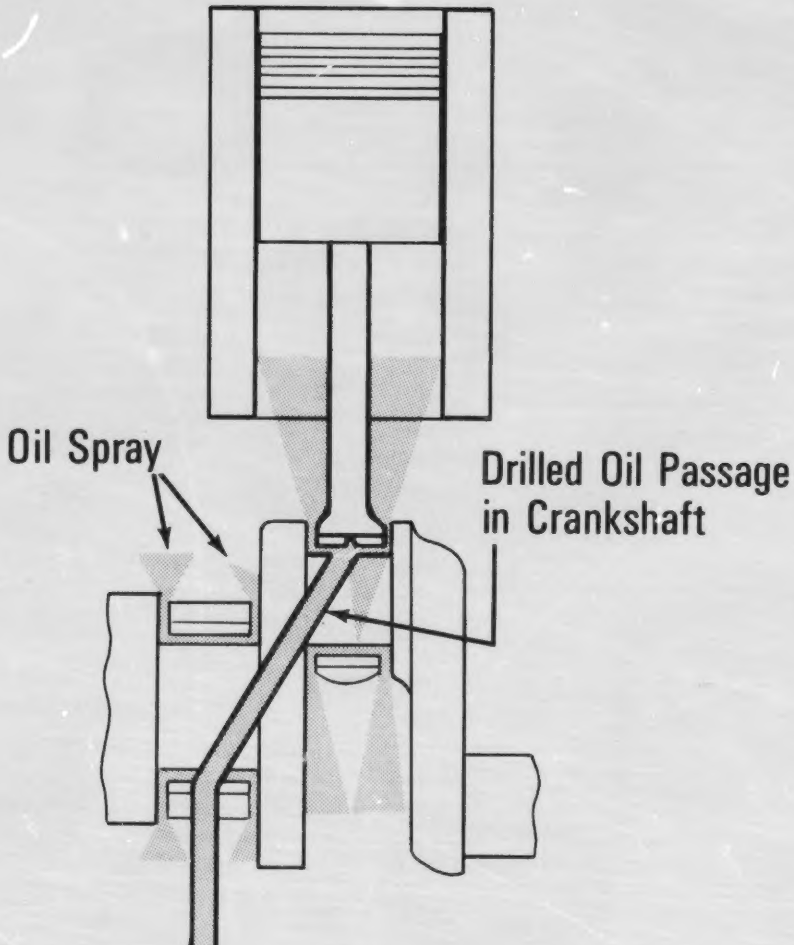
Counterweights, Vibration Damper and Flywheel


Vibration Damper
Connecting Rod Counterbalances
Crankshaft Gear
Oil Holes
Flywheel

A Six–Cylinder, Seven–Main– Bearing Crankshaft.

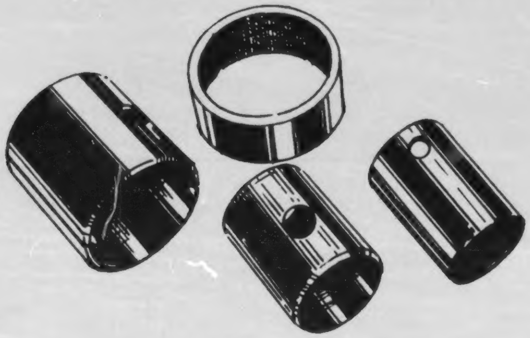
D:F - 189-C

Crankshaft Lubrication


Oil Spray
Drilled Oil Passage
in Crankshaft

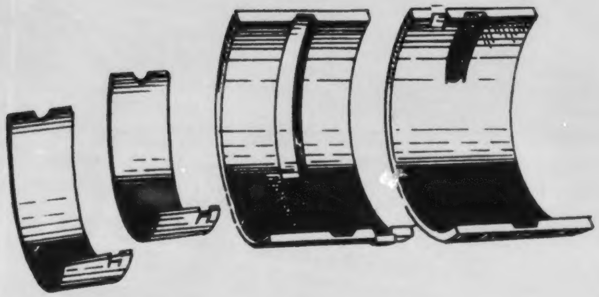
Bushings and Bearings

Bushings



For Light Loads

Bearings

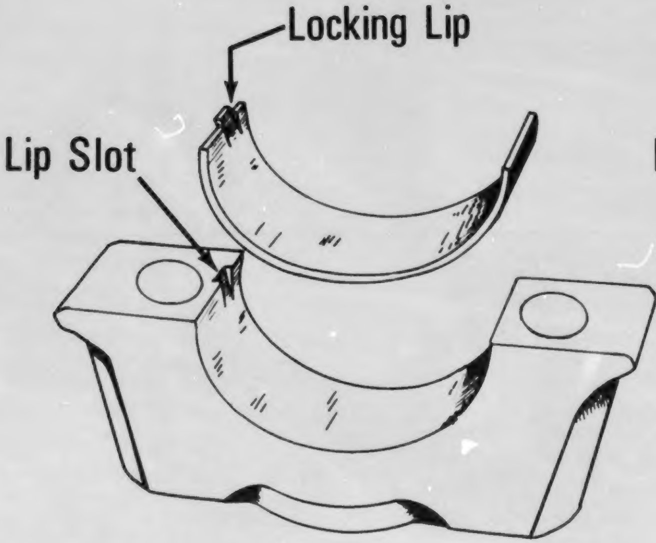


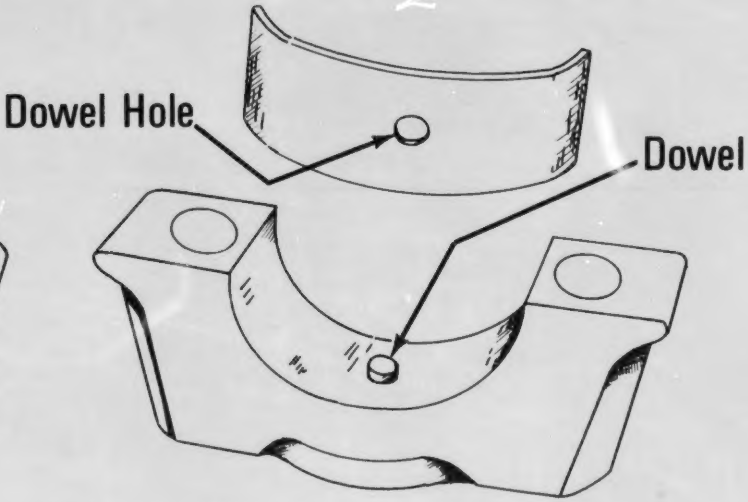
For Heavy Loads

TM 6

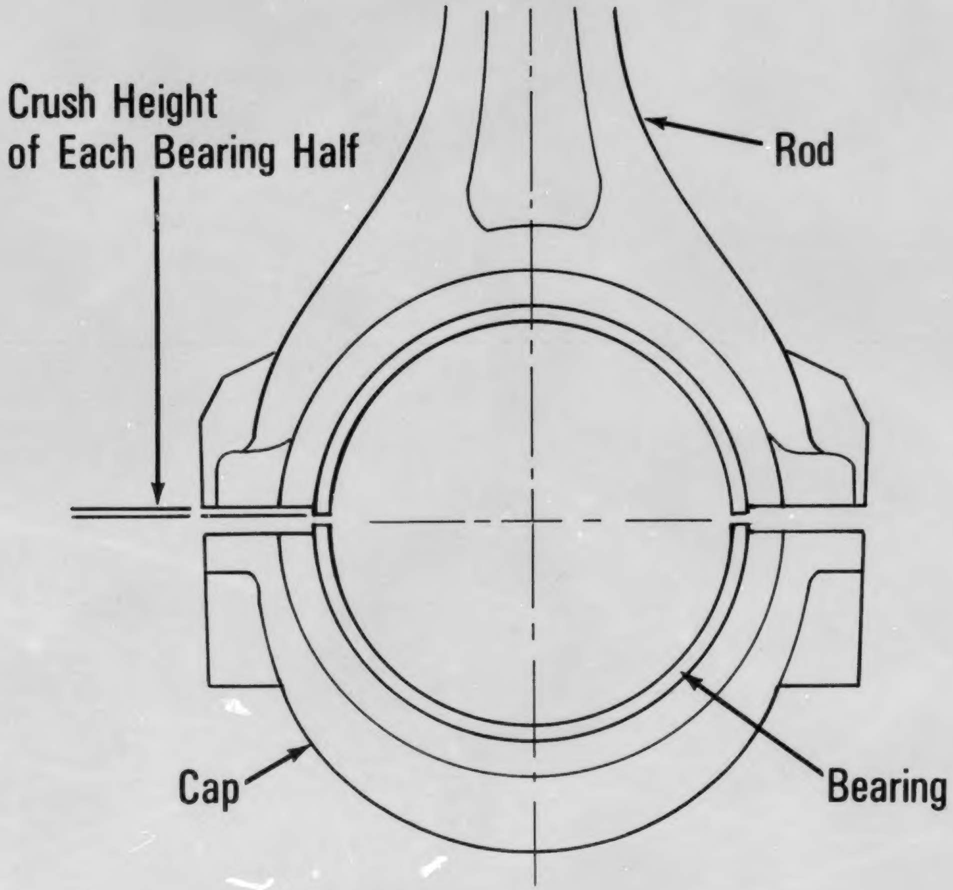
D:F - 191-C

Bearing Locks

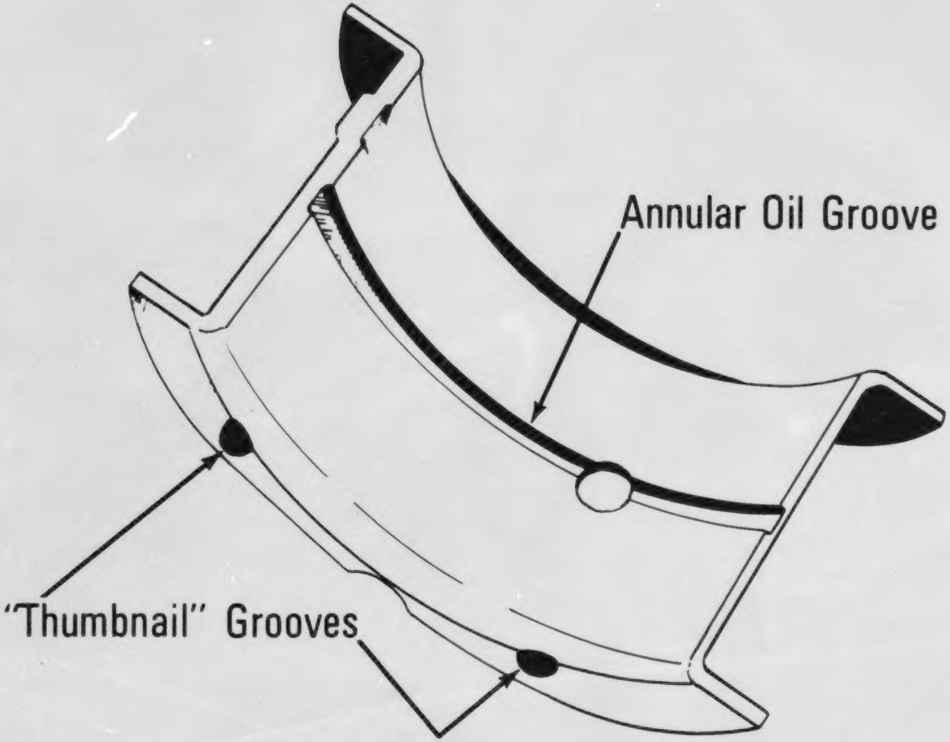

Locking Lip
Lip Slot


Dowel Hole
Dowel

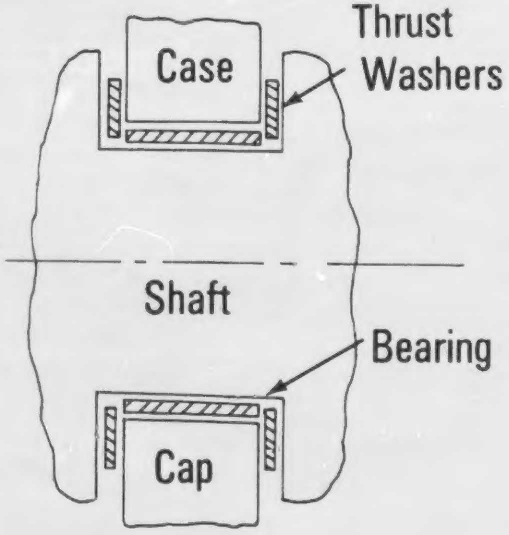
Bearing Crush


Crush Height
of Each Bearing Half
Rod
Cap
Bearing

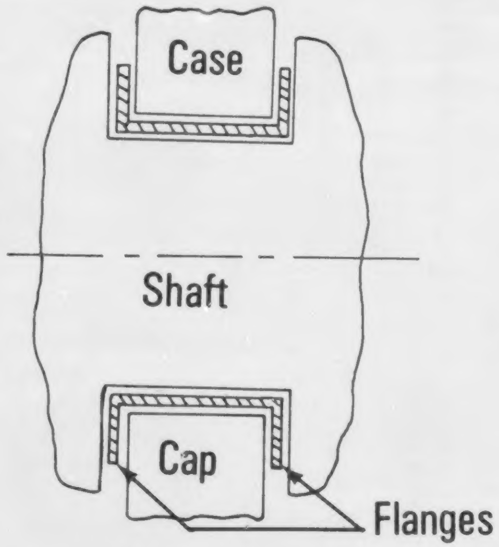
Bearing Oil Grooves


Annular Oil Groove
"Thumbnail" Grooves

Types of Thrust Bearings

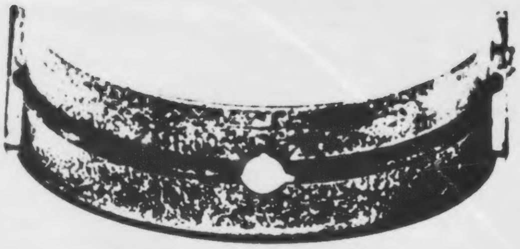

Case
Thrust Washers
Shaft
Bearing
Cap

Separate Thrust Washers

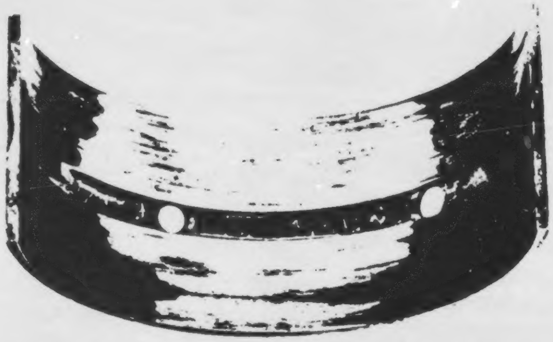

Case
Shaft
Cap
Flanges

Thrust Flanges on Bearing

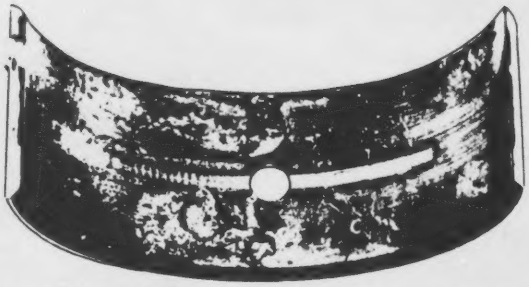
Causes of Bearing Failure



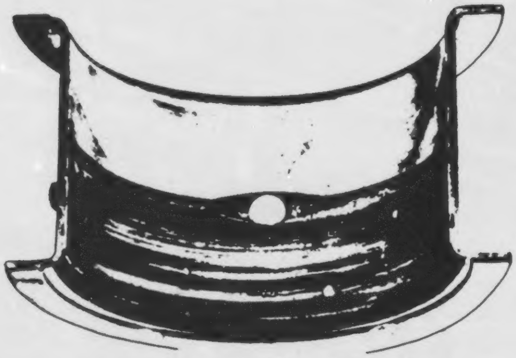
Damage From Dirt
Embedded In Bearing



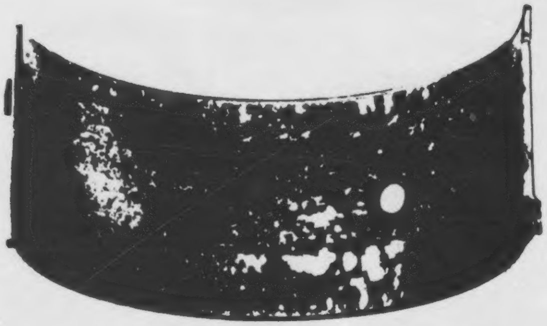
Oil Starvation Caused This Damage



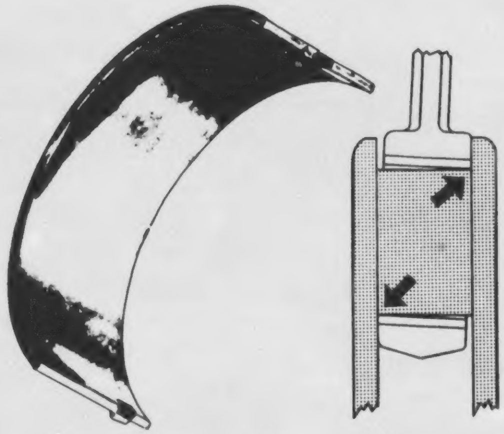
Bearing Fatigue Caused By
Overloading and Heat



Wear On One Edge of Bearing
Caused by Tapered Journals



Corrosion From Acid
Formation In Oil



Excessive Wear Caused
by a Bent Connecting Rod

CRANKSHAFTS AND BEARINGS
UNIT V

JOB SHEET #1--REMOVE A CRANKSHAFT

I. Tools and materials

A. Engine

B. Appropriate service manual

C. Basic hand tool set

D. Marking set

Example: Punch, chisel, letter or number marking set

E. Clean shop towels

F. Lifting device

G. Fan belts in good condition

II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Refer to Unit II, Piston and Connecting Rod Assemblies, for piston removal information.)

A. Mark main bearing caps and side of engine block for proper replacement

B. Remove main bearing cap bolts

C. Remove main bearing caps

(NOTE: Keep lower bearing shells with their caps.)

D. Attach fan belts to the two middle rod throws

E. Attach lifting device to fan belts and remove crankshaft

F. Set crankshaft on butt end and secure to stationary object

CRANKSHAFTS AND BEARINGS
UNIT V

JOB SHEET #2--INSPECT AND MEASURE A CRANKSHAFT AND BEARINGS

I. Tools and materials

A. Crankshaft

B. Appropriate service manual

C. Outside micrometer

D. Clean shop towels

E. Basic hand tool set

F. Inside micrometer

G. Cleaning rod

II. Procedure

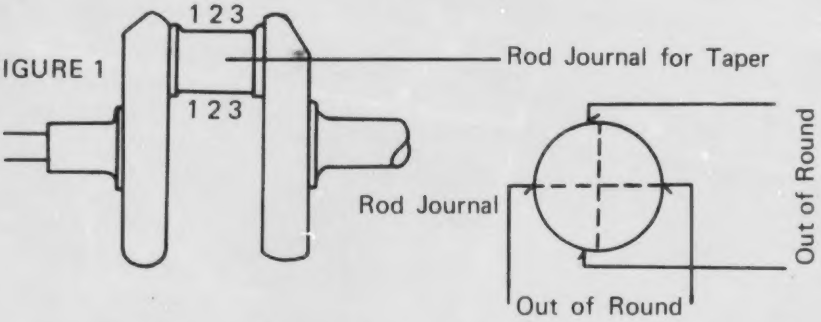
(CAUTION: Follow all shop safety procedures.)

A. Clean outside of crankshaft, paying close attention to bearing surfaces

(NOTE: Some crankshafts have pipe plugs in the drillings of the crank. Remove these and use cleaning rod and rag to clean them, and lightly oil the threads and reinstall.)

B. Using the outside micrometer, measure the connecting rod journals in three places for taper, and in two places for out-of-roundness (Figure 1)

FIGURE 1



(NOTE: To get taper, three places on the journal have to be measured. With an outside micrometer, measure at one side of journal [1], then measure middle of journal [2], and then measure at other side of journal [3].)

JOB SHEET #2

C. Record these readings on the following chart

Engine Model # or size ________________

Main Bearing #1 Taper

1.
2.
3.
4. Total taper ______________

Main Bearing #1 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #2 Taper

1.
2.
3.
4. Total taper ______________

Main Bearing #2 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #3 Taper

1.
2.
3.
4. Total taper ______________

Main Bearing #3 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #4 Taper

1.
2.
3.
4. Total taper ______________

Main Bearing #4 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #5 Taper

1.
2.
3.
4. Total taper ______________

Main Bearing #5 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #6 Taper

1.
2.
3.
4. Total taper ______________

Main Bearing #6 Out-of-Round

1.
2.
3. Total out-of-round ________________

Main Bearing #7 Taper

1.
2.
3.
4. Total taper ______________

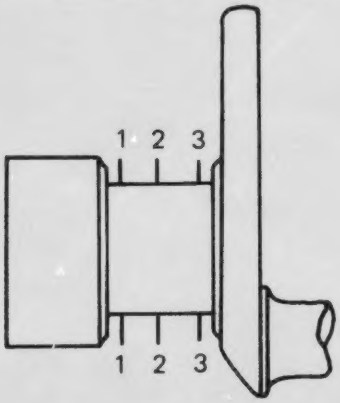
Main Bearing #7 Out-of-Round

1.
2.
3. Total out-of-round ________________

JOB SHEET #2

D. Using the same method measure the crankshaft main bearing journal (Figure 2)

FIGURE 2



(NOTE: To get taper, three places on the journal have to be measured. With an outside micrometer, measure at one side of journal [1], then measure middle of journal [2], and then measure at other side of journal [3].)

E. Record these readings on the following chart

Rod Bearing #1 Taper

1.
2.
3.
4. Total taper______________

Rod Bearing #1 Out-of-Round

1.
2.
3. Total out-of-round__________________

Rod Bearing #2 Taper

1.
2.
3.
4. Total taper______________

Rod Bearing #2 Out-of-Round

1.
2.
3. Total out-of-round__________________

Rod Bearing #3 Taper

1.
2.
3.
4. Total taper______________

Rod Bearing #3 Out-of-Round

1.
2.
3. Total out-of-round__________________

Rod Bearing #4 Taper

1.
2.
3.
4. Total taper______________

Rod Bearing #4 Out-of-Round

1.
2.
3. Total out-of-round__________________

JOB SHEET #2

Rod Bearing #5 Taper

1.
2.
3.
4. Total taper______________

Rod Bearing #6 Taper

1.
2.
3.
4. Total taper ______________

Rod Bearing #7 Taper

1.
2.
3.
4. Total taper ______________

Rod Bearing #5 Out-of-Round

1.
2.
3. Total out-of-round______________

Rob Bearing #6 Out-of-Round

1.
2.
3. Total out-of-round______________

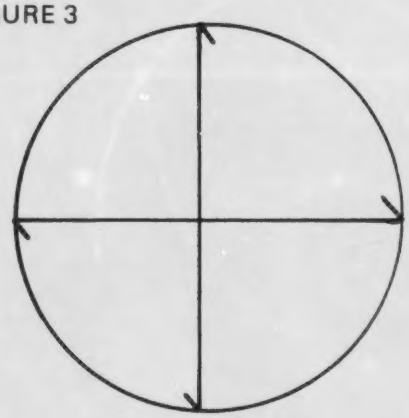
Rod Bearing #7 Out-of-Round

1.
2.
3. Total out-of-round______________

(NOTE: If crankshaft is out of specifications, send it to a machine shop and have them turn to next undersize.)

F. Place main bearing caps on the block in proper order, and using an inside micrometer, check main bearing bore for out-of-roundness (Figure 3)

FIGURE 3



(NOTE: If an out-of-round condition exists, the block will have to be line bored.)

CRANKSHAFTS AND BEARINGS
UNIT V

JOB SHEET #3--INSTALL BEARINGS AND CRANKSHAFT

I. Tools and materials

A. Engine

B. Appropriate service manual

C. Basic hand tool set

D. Pry bar

E. Torque wrench

F. Dial indicator

G. Plastigage

H. Lubriplate

I. New engine bearings

J. New lockplates if used

K. Lifting device

L. Fan belts

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Place upper crankshaft bearing halves in engine block

(NOTE: After the upper bearing halves are installed in block, make sure oil holes in bearing are lined up with oil holes in block and make sure bearing locking device on bearing lines up with recess in block.) (Figure 1)

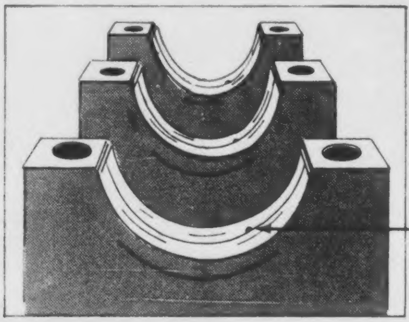


FIGURE 1

Align oil hole in bearing with oil passage

JOB SHEET #3

B. Using lifting device and fan belts, place crankshaft in block

(CAUTION: Use care not to damage crankshaft or engine bearings.)

C. Place lower bearing halves in main bearing caps

D. Place all main bearing caps except #1 in place

E. Using the proper size plastigage, break off a section long enough to go across main bearing

F. Place the plastigage off center on the bearing and place on #1 journal

G. Torque main bearing caps to specifications

H. Loosen main bearing cap #1 and remove

I. Compare flattened plastigage to plastigage scale

J. Repeat for the remaining journals

(NOTE: You will replace each cap and torque to specifications after plastigaging the journal; then rotate crankshaft to make sure it turns freely.)

K. With all main bearing caps torqued to specifications, take a pry bar and pry the crankshaft forward until it stops; remove pry bar, set dial indicator up at the rear of the block, and zero the indicator

L. Pry the crankshaft rearward and note indicator reading.

(NOTE: Refer to manufacturer's specifications for proper end play.)

M. Remove all lower main bearing halves and apply lubriplate to main bearings; retorque all main bearing cap screws to specifications.

D:F - 211-C

CRANKSHAFTS AND BEARINGS
UNIT V

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Made from a single billet of steel

_____b. That part of a shaft or axle in contact with the bearing

_____c. Two crankshaft webs and one crankpin

_____d. Forms the crank or throw between the crankpin and main journal

_____e. Outer end of crank throw

_____f. Reduces torsional stress on the crankshaft caused by power strokes and the loads on the engine

_____g. Balanced while at rest

_____h. Balanced against the rotary outward force at high speed

_____i. Full round sleeve normally used to support light loads

_____j. Half round sleeve normally used to support heavy loads

_____k. Measured difference between the inside diameter of the bearing and the outside diameter of the journal

_____l. Engine block without cylinder head and external accessories

_____m. Controls crankshaft end play

1. Dynamically balanced
2. Short block
3. Crankpin
4. Bushing
5. Vibration damper
6. Statically balanced
7. Bearing
8. Crankshaft throw
9. Crankshaft web
10. Journal
11. Integral crankshaft
12. Bearing clearance
13. Thrust bearing

2. Name four types of crankshaft construction.

a. ____

b. ____

c. ____

d. ____

3. Name six parts of a crankshaft.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

4. List three effects of the arrangement of crankshaft throws.

   a. ______________________________

   b. ______________________________

   c. ______________________________

5. Match the arrangement of crankshaft throws on the right with the number of cylinders in the engine.

_____a. Two and four cylinder	1. Throws 90° apart
_____b. Three and six cylinder	2. Throws 180° apart
_____c. Eight cylinder	3. Throws 120° apart

6. Name three ways crankshaft balance is maintained.

   a. ______________________________

   b. ______________________________

   c. ______________________________

7. Select true statements concerning the lubrication of the crankshaft and surrounding parts by placing an "X" in the appropriate blanks.

   _____a. Oil pressure through crankshaft lubricates rod and main bearing

   _____b. Excess oil from rod and main bearing lubricates surrounding parts

8. Distinguish between a bushing and a bearing by placing an "X" next to the description of a bushing.

   _____a. A half round sleeve used to support heavy loads and high speeds

   _____b. A fully round sleeve used to support light loads and slow speeds

9. Name three materials used in making bearing linings.

   a. ______________________________

   b. ______________________________

   c. ______________________________

10. Name two types of bearing locks.

    a. ____

    b. ____

11. Define bearing crush.

    ____

    ____

12. State the purpose of oil grooves in the bearing.

    ____

    ____

13. Name two types of thrust bearings.

    a. ____

    b. ____

14. List three engine indications of bearing failure.

    a. ____

    b. ____

    c. ____

15. Match the percentages of bearing failure on the right with the causes of bearing failure.

_____a. Dirt	1. 9 percent
_____b. Lack of lubrication	2. 14 percent
_____c. Improper assembly	3. 16 percent
_____d. Misalignment	4. 10 percent
_____e. Overloading	5. 43 percent

16. List four functions of the flywheel.

    a. ____

    b. ____

    c. ____

    d. ____

17. Demonstrate the ability to:

    a. Remove a crankshaft.

    b. Inspect and measure a crankshaft and bearings.

    c. Install bearings and crankshaft.

    (NOTE: If these activities have not been accomplished prior to the test, ask you instructor when they should be completed.)

CRANKSHAFTS AND BEARINGS
UNIT V

ANSWERS TO TEST

1. a. 11
   b. 10
   c. 8
   d. 9
   e. 3
   f. 5
   g. 6
   h. 1
   i. 4
   j. 7
   k. 12
   l. 2
   m. 13

2. a. Integral
   b. Sectional
   c. Semi-built-up
   d. Built-up

3. a. Main bearing journals
   b. Connecting rod bearing journals
   c. Connecting rod counterweights
   d. Flywheel hub or flange
   e. Crankshaft gear
   f. Crankshaft throw

4. Any three of the following:

   a. Balance the engine
   b. Smooth vibrations of turning shaft
   c. Equalize loads on the main bearings
   d. Determine the firing order of engine

5. a. 2
   b. 3
   c. 1

6. a. Counterweights
   b. Vibration damper
   c. Flywheel

7. a, b

8. b

9. a. Tin or lead base babbit
   b. Copper or aluminum alloys
   c. Multilayers of copper or aluminum alloys and silver combinations

10. a. Lip slot
    b. Dowel

11. Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened

12. Bearing oil grooves carry the oil through to the connecting rod

13. a. Separate thrust washers
    b. Thrust flanges on bearings

14. a. Drop in lubricating oil pressure
    b. Excessive oil consumption
    c. Engine noise--Rhythmic knock

15. a. 5
    b. 3
    c. 2
    d. 4
    e. 1

16. Any four of the following:

    a. Stores energy for momentum between power strokes
    b. Smooths out speed of crankshaft
    c. Transmits power to driven machine
    d. Provides a drive for starter via ring gear
    e. Serves as a facing for engine clutch

17. Performance skills evaluated to the satisfaction of the instructor

LUBRICATION SYSTEMS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components of the lubrication system and match the components with their purposes. The student should also be able to check and adjust oil pressure on a live engine and change an oil filter. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the lubrication system with the correct definitions.
2. List five functions of the lubrication system.
3. List three types of lubrication systems.
4. Identify the components of the lubrication system.
5. Match the components of the lubrication system with their purposes.
6. Identify two types of oil filters.
7. Name types of oil pumps.
8. List sources of oil contamination.
9. List the purposes of lubricating valves.
10. Distinguish between internally and externally mounted oil coolers.
11. Select true statements concerning mechanical and electrical oil pressure indicating systems.
12. Demonstrate the ability to:
    a. Check and adjust oil pressure on a live engine.
    b. Change an oil filter.

LUBRICATION SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Invite company representative to discuss lubricating oils.

VIII. Have students make a list of oil contaminants.

IX. Make a display of different oil filter types.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Functions of the Lubrication System
      2. TM 2--Types of Lubrication Systems
      3. TM 3--Components of the Lubrication System
      4. TM 4--Types of Oil Filters
      5. TM 5--Types of Oil Pumps
      6. TM 6--Types of Oil Pumps (Continued)
      7. TM 7--Types of Oil Pumps (Continued)
      8. TM 8--Lubricating Valves
      9. TM 9--Oil Coolers

10. TM 10--Mechanical Oil Pressure Indicating System
11. TM 11--Electrical Oil Pressure Indicating System

D. Job sheets

1. Job Sheet #1--Check and Adjust Oil Pressure on a Live Engine
2. Job Sheet #2--Change an Oil Filter

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J. and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines.* 5th ed. Moline, Illinois: Deere and Company, 1980.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc. 1982.

LUBRICATION SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

   A. Friction--Resistance to movement between any two objects placed in contact with each other

   B. Viscosity--Measure of an oil's ability to flow

   C. API--American Petroleum Institute

   D. SAE--Society of Automotive Engineers

   E. Gallery--Pipe or passageway in the engine used to carry engine oil from one area to another

II. Functions of the lubrication system (Transparency 1)

   A. Reduces friction between moving parts

   B. Absorbs and dissipates heat

   C. Seals the piston rings and cylinder walls

   D. Cleans and flushes moving parts

   E. Helps deaden the noise of the engine

III. Types of lubrication systems (Transparency 2)

   A. Circulating splash

   B. Internal force feed and splash

   C. Full internal force feed

   (NOTE: The full internal force feed system, in addition to other parts, supplies oil under pressure to the piston pins.)

IV. Components of the lubrication system (Transparency 3)

   A. Oil galleries

   B. Oil filter

   C. Pressure regulating valve

INFORMATION SHEET

D. Oil pump

E. Oil pan

F. Pressure gauge

G. Engine bearings

V. Purposes of components of the lubrication system

A. Oil galleries--Carry engine oil from one area to another

B. Oil filter--Strains the engine oil removing abrasive particles

C. Pressure regulating valve--Limits the maximum oil pressure

D. Oil pump--Forces oil under pressure to various parts of the engine for lubrication

E. Oil pan--Provides a reservoir for the engine oil

F. Pressure gauge--Indicates oil pressure during engine operation

G. Oil cooler-Engine coolant flows through this and helps dissipate the heat in the engine oil

VI. Types of oil filters (Transparency 4)

A. Surface filter--Wire mesh type

(NOTE: Oil passes straight through tiny surface holes.)

B. Depth filter--Cotton waste type

(NOTE: Oil moves in many directions before passing through filter to lubrication system.)

VII. Types of oil pumps (Transparencies 5, 6, and 7)

A. Gear

B. Rotor

C. Vane

(NOTE: All types are positive displacement pumps.)

INFORMATION SHEET

VIII. Sources of oil contamination

- A. Storing and handling
- B. Dust from air that is breathed into engine
- C. Improper engine warm-up
- D. Antifreeze leaking into oil supply
- E. Oxidation
- F. Carbon particles
- G. Engine wear
- H. Fuel dilution

IX. Purposes of lubricating valves (Transparency 8)

- A. Regulate oil pressure
- B. Bypass oil at filters and oil coolers

(NOTE: The oil pressure regulating valve maintains the correct pressure in the lubricating system regardless of engine speed or the temperature of the oil.)

X. Oil cooler circulation (Transparency 9)

- A. Internally mounted--Engine coolant is pumped by water pump through oil cooler mounted in the crankcase and back to the radiator where the heat is dissipated
- B. Externally mounted--Both water and oil are pumped through the oil cooler

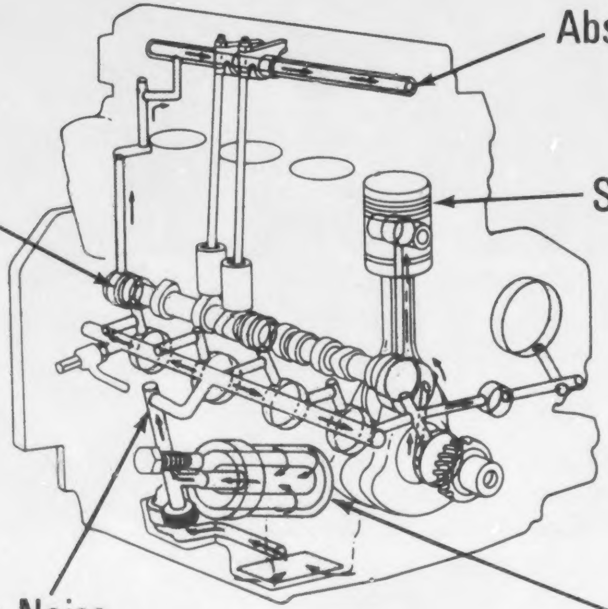
(NOTE: Oil coolers are also known as heat exchangers.)

XI. Oil pressure indicating systems

- A. Mechanical--Bourdon tube gauge which tends to straighten out when pressure is applied (Transparency 10)
- B. Electrical (Transparency 11)
  - 1. Sending unit is at pressure source
  - 2. Indicating gauge is on control panel

(NOTE: Electrical indicating systems may be three types: electromagnetic coil, heating coil, or pressure switch system.)

Functions of the Lubrication System



Absorbs Heat

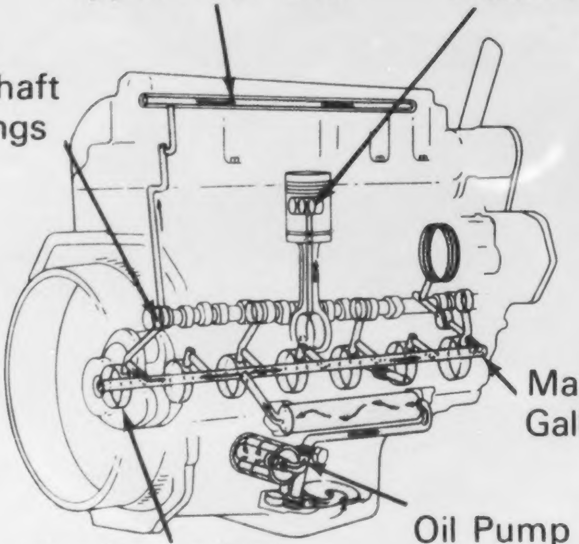
Reduces Friction and Wear

Seals Piston Rings

Deadens Noise

Cleans Parts

Types of Lubrication Systems



Tappet Lever Shaft

Piston Pin Bearing

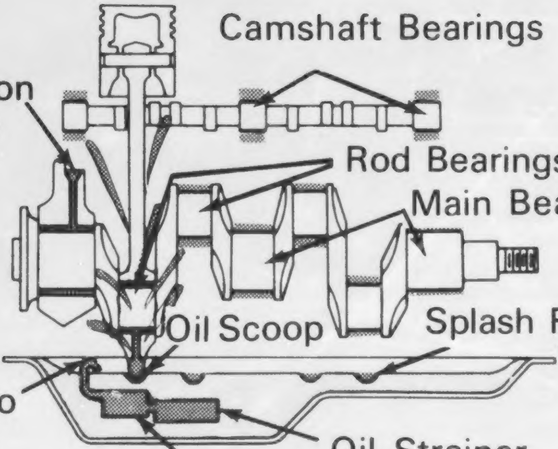
Camshaft Bearings

Main Oil Gallery

Oil Pump and Filters

Crankshaft Main Bearings

Full Internal Force Feed



Camshaft Bearings

Oil Collection Trough

Rod Bearings

Main Bearings

Oil Scoop

Splash Pan Troughs

Oil Supply to Splash Pan

Oil Strainer

Oil Pump

Circulating Splash System

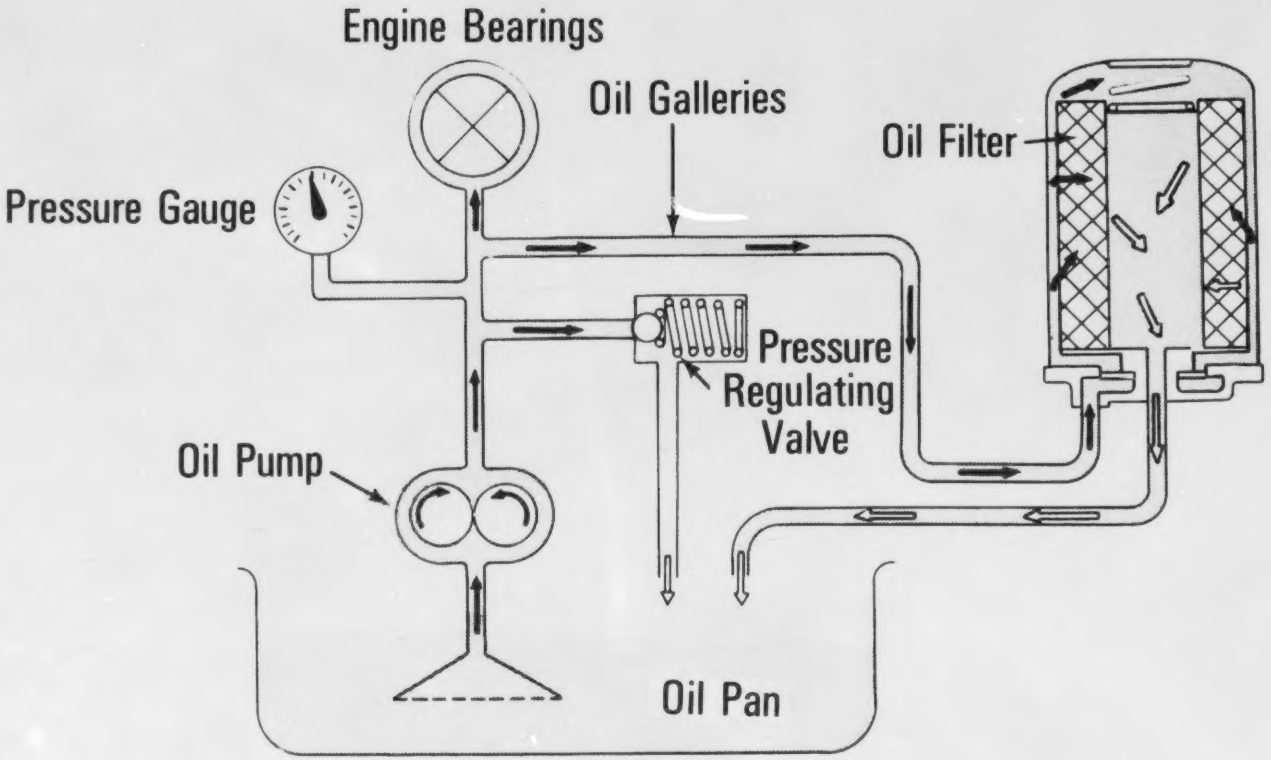
TM 2

643

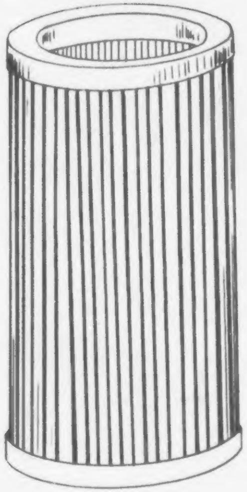
644

D:F - 11-D

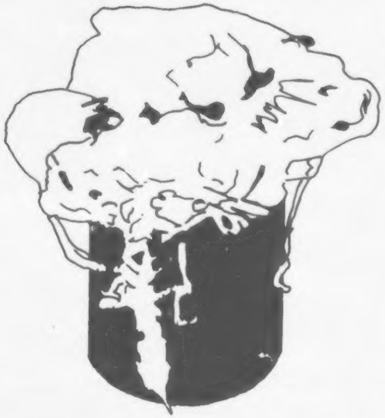
Components of the Lubrication System


Engine Bearings
Oil Galleries
Oil Filter
Pressure Gauge
Pressure Regulating Valve
Oil Pump
Oil Pan

Types of Oil Filters

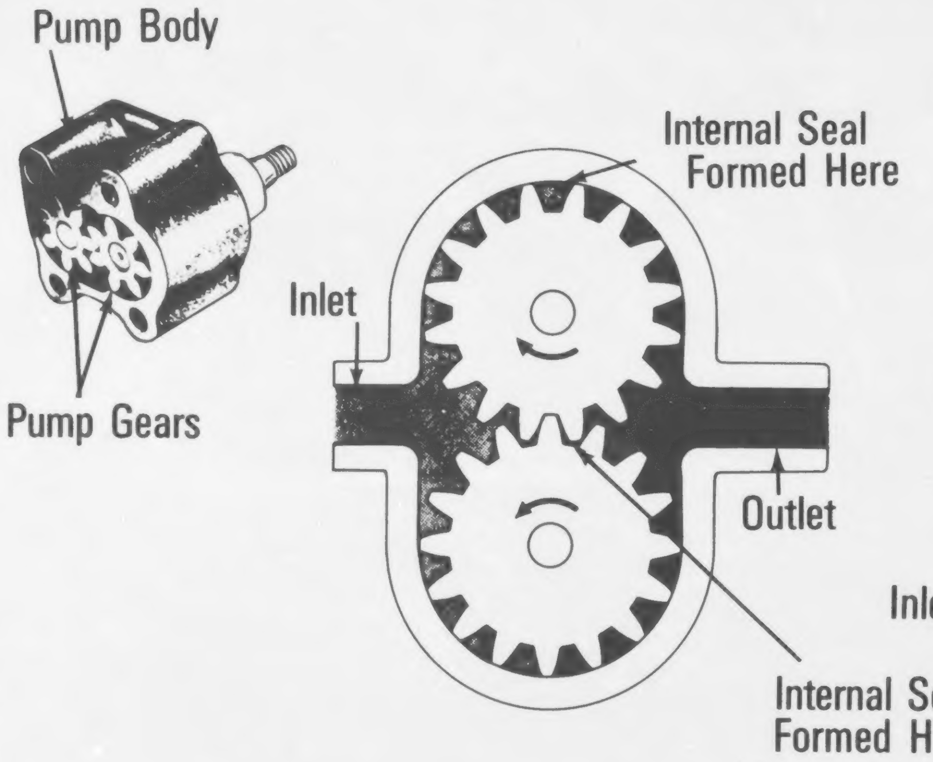


Surface Filter--Wire Mesh Type

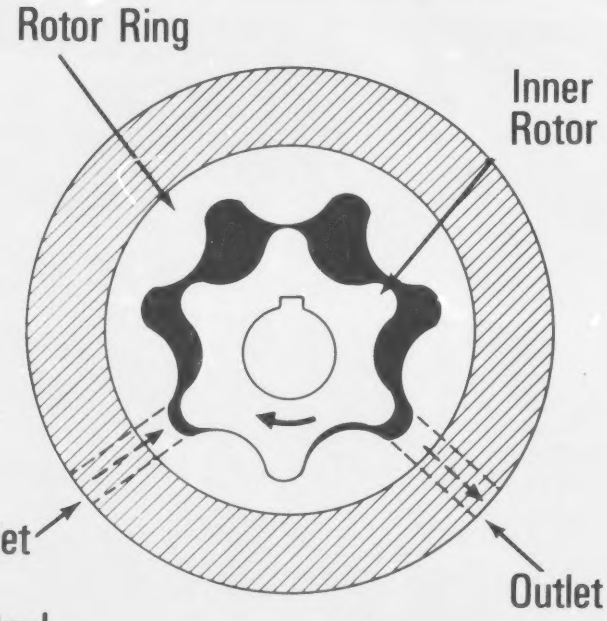


Depth Filter--Cotton Waste Type

Types of Oil Pumps

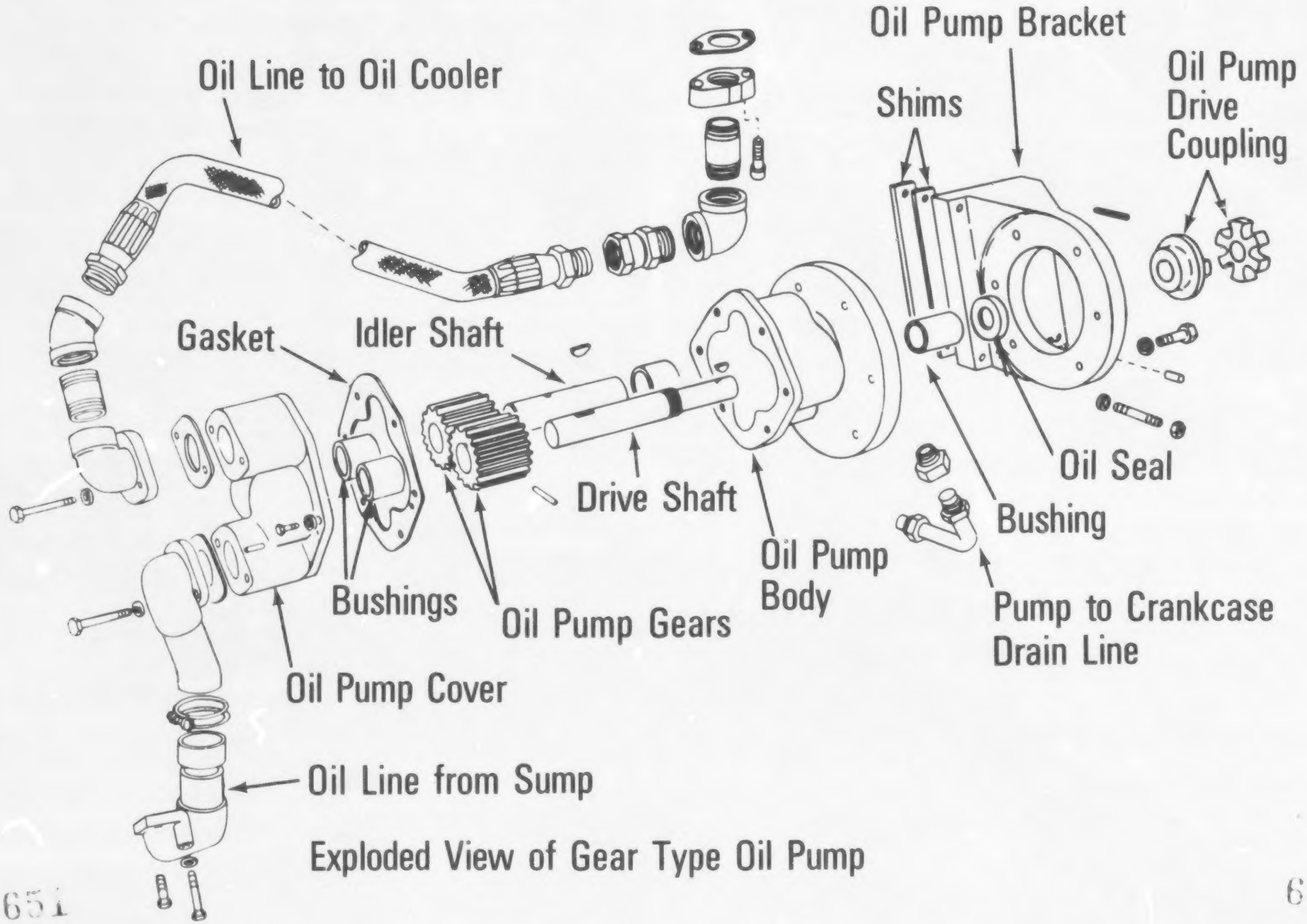

Pump Body
Pump Gears
Internal Seal Formed Here
Inlet
Outlet
Internal Seal Formed Here

External Gear Pump


Rotor Ring
Inner Rotor
Inlet
Outlet

Rotor Pump

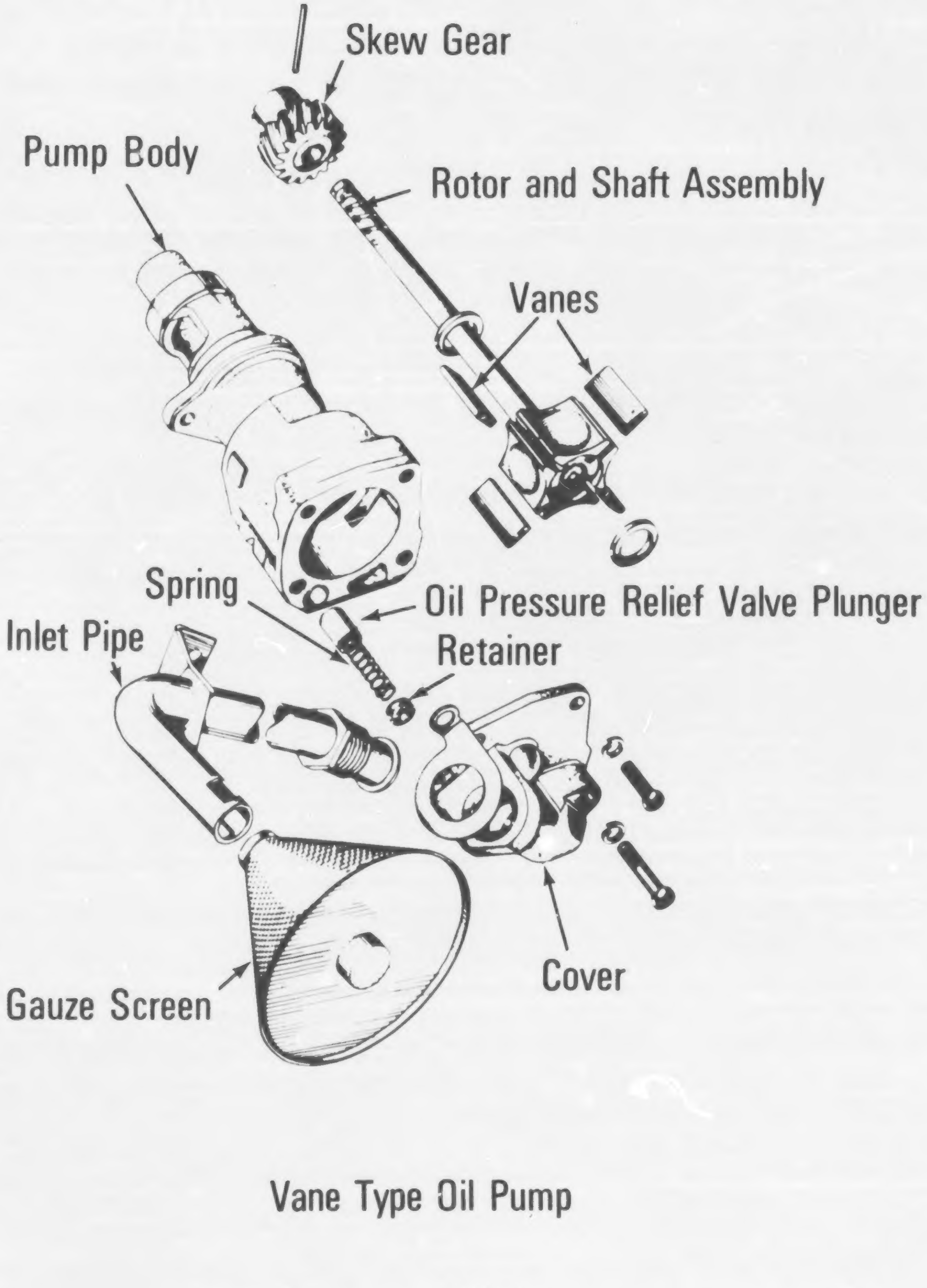
Types of Oil Pumps (Continued)


Oil Line to Oil Cooler
Oil Pump Bracket
Shims
Oil Pump Drive Coupling
Gasket
Idler Shaft
Drive Shaft
Oil Seal
Bushing
Bushings
Oil Pump Gears
Oil Pump Body
Pump to Crankcase Drain Line
Oil Pump Cover
Oil Line from Sump

Exploded View of Gear Type Oil Pump

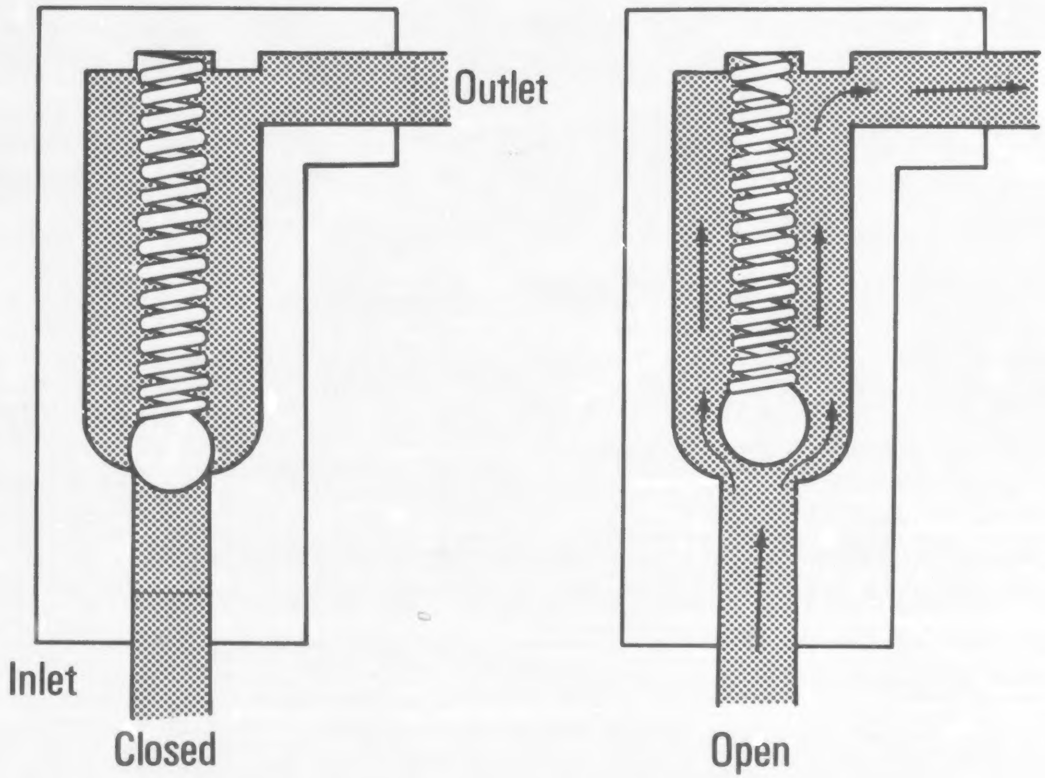
Types of Oil Pumps

(Continued)


Skew Gear
Pump Body
Rotor and Shaft Assembly
Vanes
Spring
Oil Pressure Relief Valve Plunger
Inlet Pipe
Retainer
Cover
Gauze Screen

Vane Type Oil Pump

Lubricating Valves


Outlet
Inlet
Closed
Open

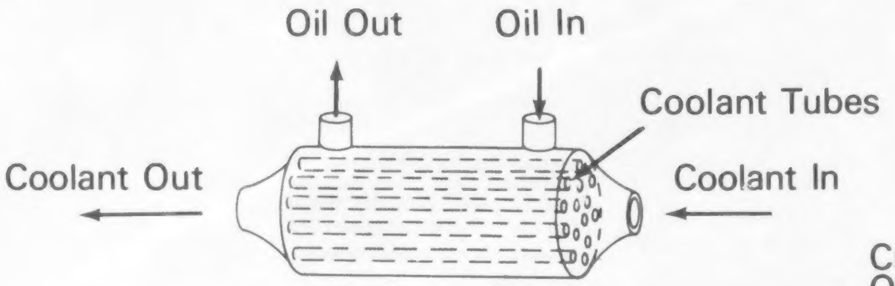
TM 8

654

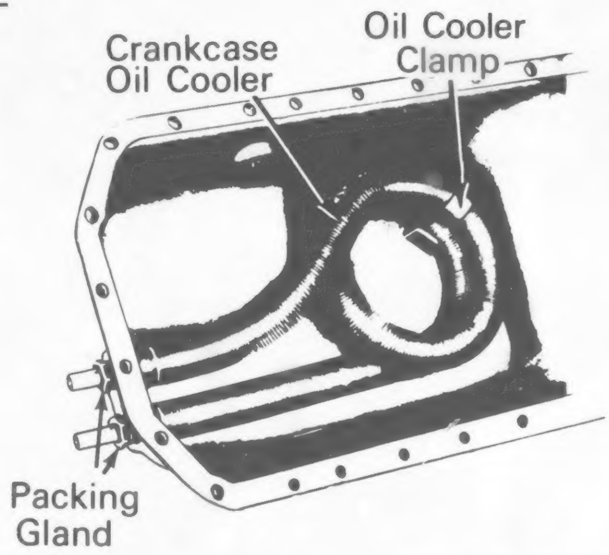
655

D:F - 23-D

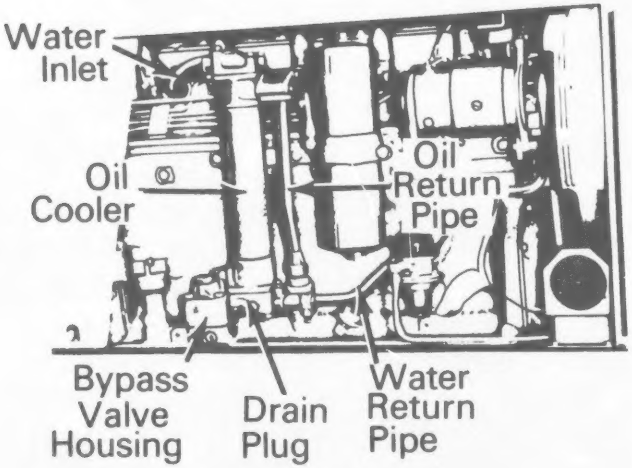
Oil Coolers


Oil Out
Oil In
Coolant Tubes
Coolant Out
Coolant In

Operation of Engine Oil Cooler

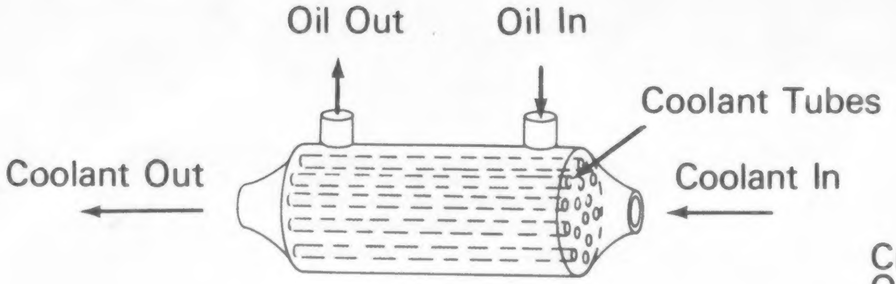

Crankcase Oil Cooler
Oil Cooler Clamp
Packing Gland

Externally Mounted

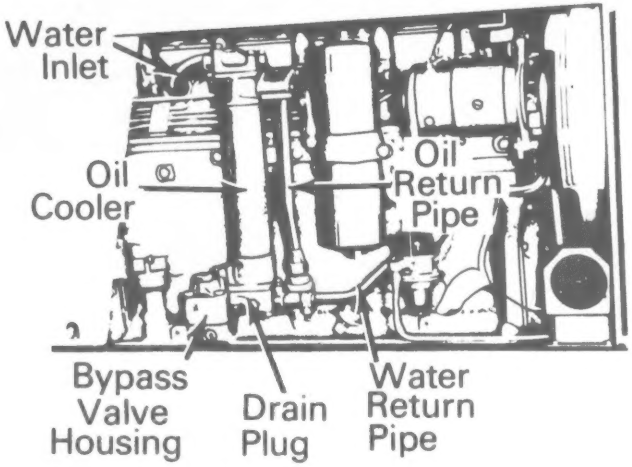

Water Inlet
Oil Cooler
Oil Return Pipe
Bypass Valve Housing
Drain Plug
Water Return Pipe

Internally Mounted

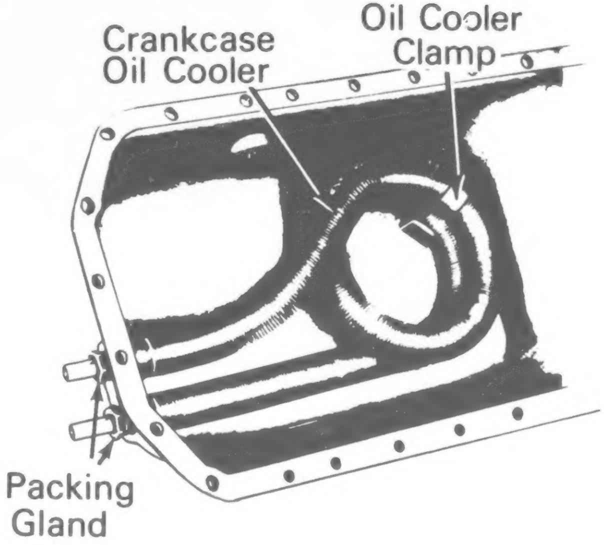
Oil Coolers


Oil Out
Oil In
Coolant Tubes
Coolant Out
Coolant In

Operation of Engine Oil Cooler


Water Inlet
Oil Cooler
Oil Return Pipe
Bypass Valve Housing
Drain Plug
Water Return Pipe

Internally Mounted

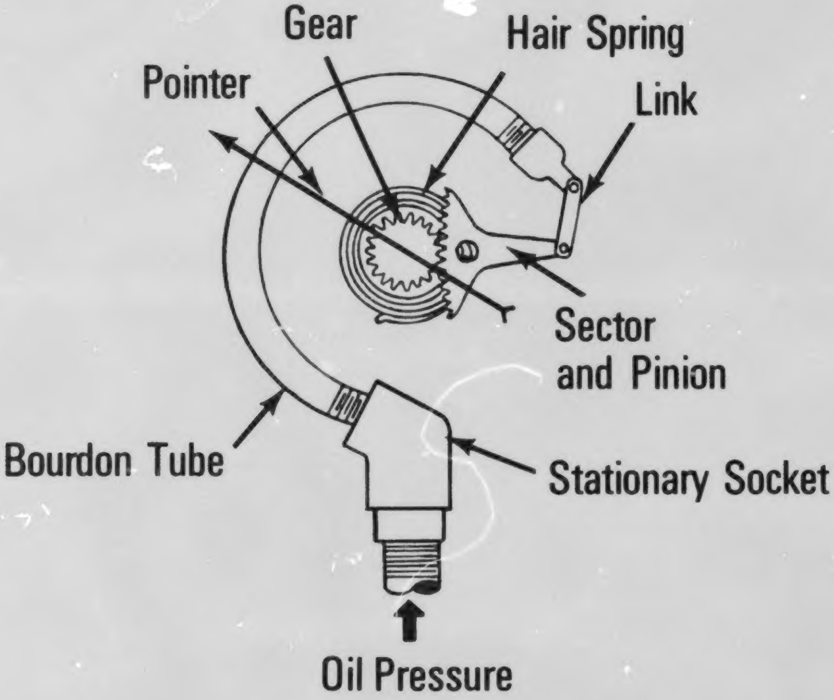

Crankcase Oil Cooler
Oil Cooler Clamp
Packing Gland

Externally Mounted

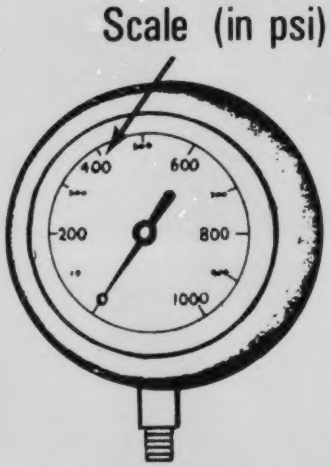
TM 9

D:F - 25-D

Mechanical Oil Pressure Indicating System


Gear
Hair Spring
Pointer
Link
Sector and Pinion
Bourdon Tube
Stationary Socket
Oil Pressure

Bourdon Tube Oil Gauge


Scale (in psi)
0
200
400
600
800
1000

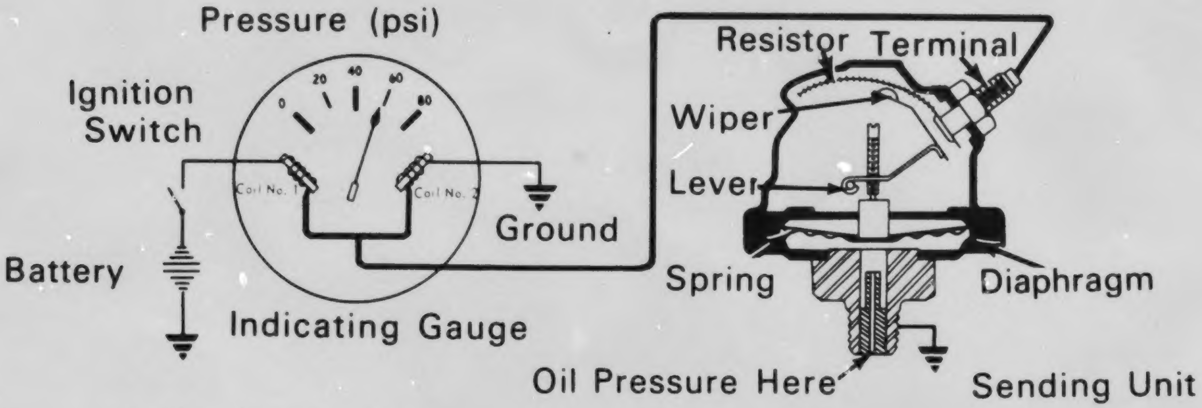
Complete Gauge

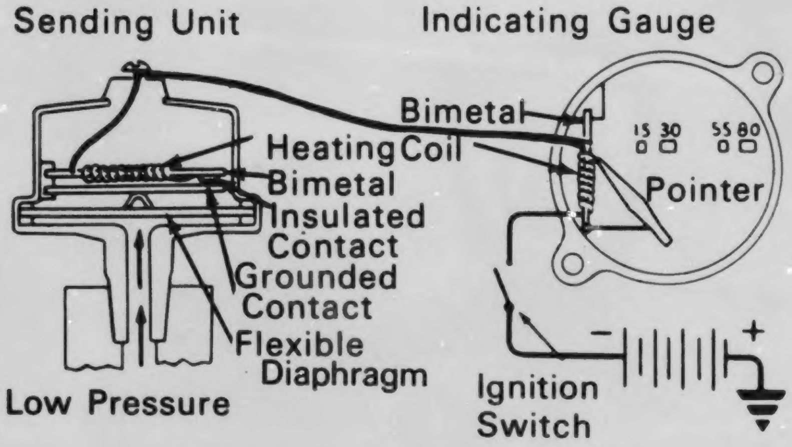
660

661

Electrical Oil Pressure Indicating Systems

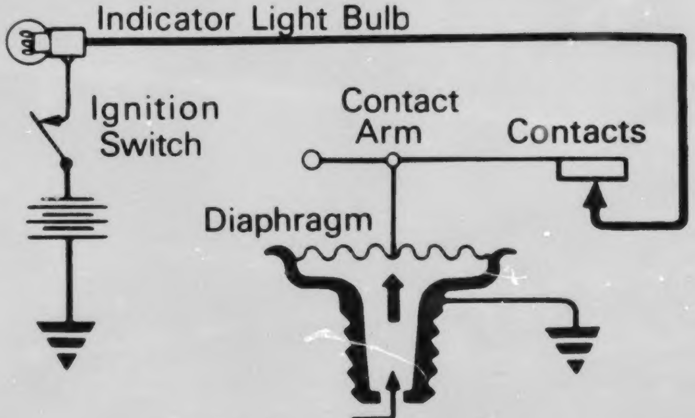
Electromagnetic Coil System for Indicating Oil Pressure


Pressure (psi)
0
20
40
60
80
Ignition Switch
Coil No. 1
Coil No. 2
Ground
Battery
Indicating Gauge
Resistor
Terminal
Wiper
Lever
Spring
Diaphragm
Oil Pressure Here
Sending Unit


Sending Unit
Indicating Gauge
Bimetal
Heating Coil
Bimetal
Insulated Contact
Grounded Contact
Flexible Diaphragm
15 30
55 80
Pointer
Low Pressure
Ignition Switch
-
+

Operation with Low Oil Pressure

Heating Coil System for Indicating Oil Pressure


Indicator Light Bulb
Ignition Switch
Contact Arm
Contacts
Diaphragm

Oil Pressure
Sending Unit (Pressure Switch)

Pressure Switch System for Indicating Oil Pressure

TM 11

D:F - 29-D

LUBRICATION SYSTEMS
UNIT I

JOB SHEET #1--CHECK AND ADJUST OIL PRESSURE ON A LIVE ENGINE

I. Tools and equipment

   A. Screwdriver

   B. Master pressure gauge

   C. End wrench

   D. Shop towel

   E. Shim stock for regulating valve

   F. Safety glasses

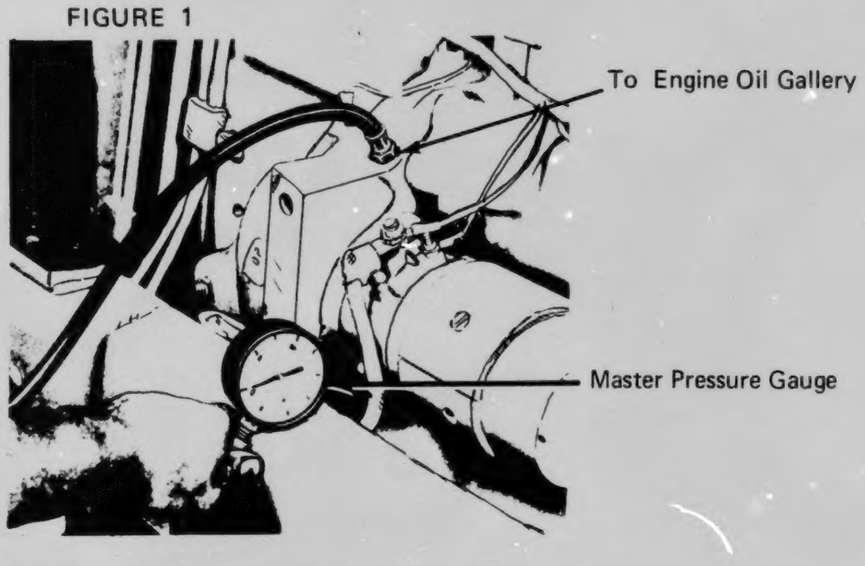
II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Check condition of oil filter; replace if dirty

   B. Install a master gauge (Figure 1)

FIGURE 1



   C. Start engine and warm up at fast idle speed

   D. Record pressure reading on the gauge

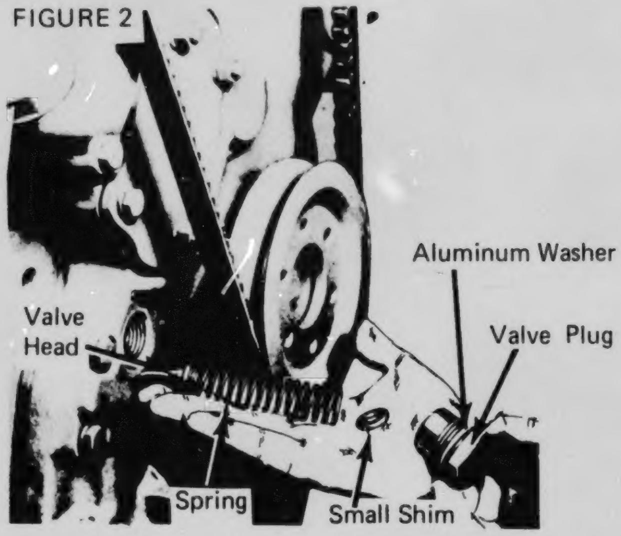
   E. Compare reading with the engine specifications

JOB SHEET #1

F. Adjust pressure regulating valve

1. Adjust pressure regulating valve with shims or adjusting screw (Figure 2)

FIGURE 2

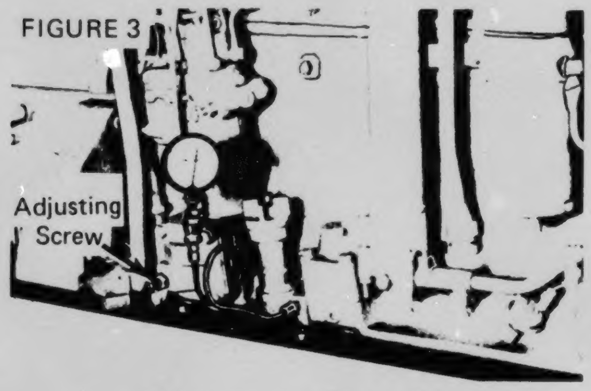

Aluminum Washer
Valve Head
Valve Plug
Spring
Small Shim

   a. Raise pressure by adding shims (if needed)

   b. Lower pressure by removing shims (if needed)

2. Adjust pressure regulating valve with screw (Figure 3)

FIGURE 3


Adjusting Screw

   a. Raise pressure by turning screw in

   b. Lower pressure by turning screw out

LUBRICATION SYSTEMS
UNIT I

JOB SHEET #2–CHANGE AN OIL FILTER

I. Tools and equipment

  A. Engine

  B. Appropriate service manual

  C. Shop towels

  D. Container to catch waste oil

  E. Suitable wrenches to remove filter

  F. Jack

  G. Jack stands

II. Procedure

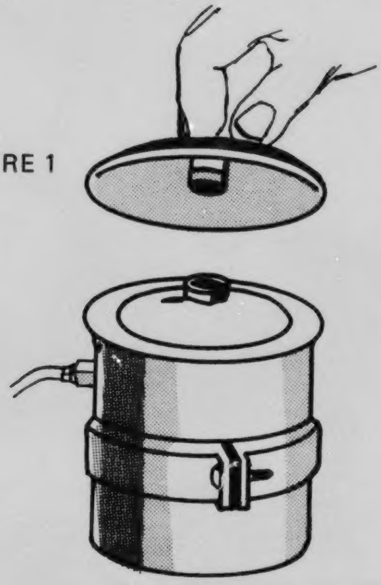
  (CAUTION: Follow all shop safety procedures.)

  A. Change replaceable element type oil filter on upper part of engine

    1. Clean dirt from filter cover

    2. Remove oil filter cover (Figure 1)

FIGURE 1



JOB SHEET #2

3. Remove oil filter element

   (NOTE: Use care to avoid spilling oil on vehicle.)

4. Remove remaining oil from filter housing by removing drain plug from housing or use the suction gun to draw out the oil

5. Clean filter cover and housing

6. Remove old filter gasket

7. Install new filter gasket into filter cover

   (NOTE: Install other small rubber gaskets as required.)

8. Install new filter element

9. Install filter cover

   (NOTE: Make sure the gasket is in place.)

10. Tighten filter cover securely

11. Add oil or refill crankcase as required

12. Start engine

13. Check for leaks

14. Shut off engine

15. Check oil level on dipstick

    (NOTE: Add oil as required. Do not overfill.)

16. Make out service sticker indicating date and mileage oil filter was changed

B. Change replaceable element type oil filter on lower part of engine

   1. Support front of vehicle on jack stands

   2. Position drain pan under oil filter

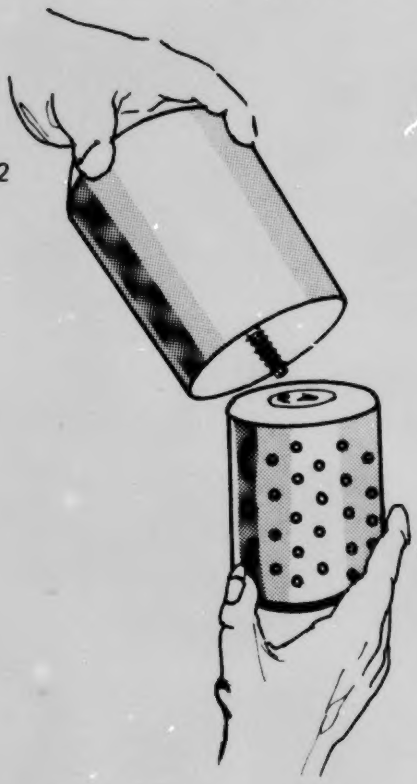
   3. Remove oil filter housing bolt

   4. Remove oil filter housing

JOB SHEET #2

5. Remove oil filter element from filter housing (Figure 2)

FIGURE 2



6. Clean the filter housing

7. Remove old oil filter housing gasket

8. Install new oil filter housing gasket

   (NOTE: Make sure the new gasket is placed correctly.)

9. Install new oil filter element in filter housing

10. Install oil filter housing and tighten bolt securely

11. Remove jack stands and lower truck to floor

12. Add oil or refill crankcase as required

13. Start engine

14. Check for leaks

JOB SHEET #2

15. Shut off engine

16. Check oil level on dipstick

    (NOTE: Add oil as required. Do not overfill.)

17. Make out service sticker indicating date and mileage oil filter was changed

C. Change sealed cartridge type oil filter

1. Support front of vehicle on jack stands if required

2. Place drain pan under oil filter

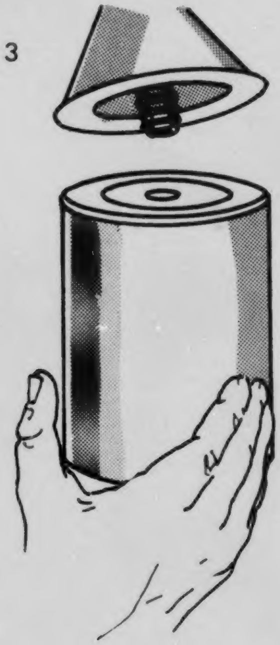
3. Remove oil filter cartridge with suitable tool

   (NOTE: Turn counterclockwise to remove.)

4. Lubricate the sealing gasket on the new oil filter cartridge with clean motor oil if required

5. Replace oil filter cartridge; tighten to manufacturer's recommendation (Figure 3)

FIGURE 3



Changing Sealed Cartridge Oil Filter

(NOTE: Usually hand tightening is sufficient.)

JOB SHEET #2

6. Remove jack stands and lower truck to floor
7. Add oil or refill crankcase as required
8. Start engine
9. Check for leaks
10. Shut off engine
11. Check oil level on dipstick

    (NOTE: Add oil as required. Do not overfill.)
12. Make out service sticker indicating date and mileage oil filter was changed

LUBRICATION SYSTEMS
UNIT I

NAME____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a.	American Petroleum Institute	1.	Viscosity
_____b.	Resistance to movement between any two objects placed in contact with each other	2.	Gallery
		3.	Friction
_____c.	Society of Automotive Engineers	4.	API
_____d.	Measure of an oil's ability to flow	5.	SAE
_____e.	Pipe or passageway in the engine used to carry engine oil from one area to another		

2. List five functions of the lubrication system.

a. ____

b. ____

c. ____

d. ____

e. ____

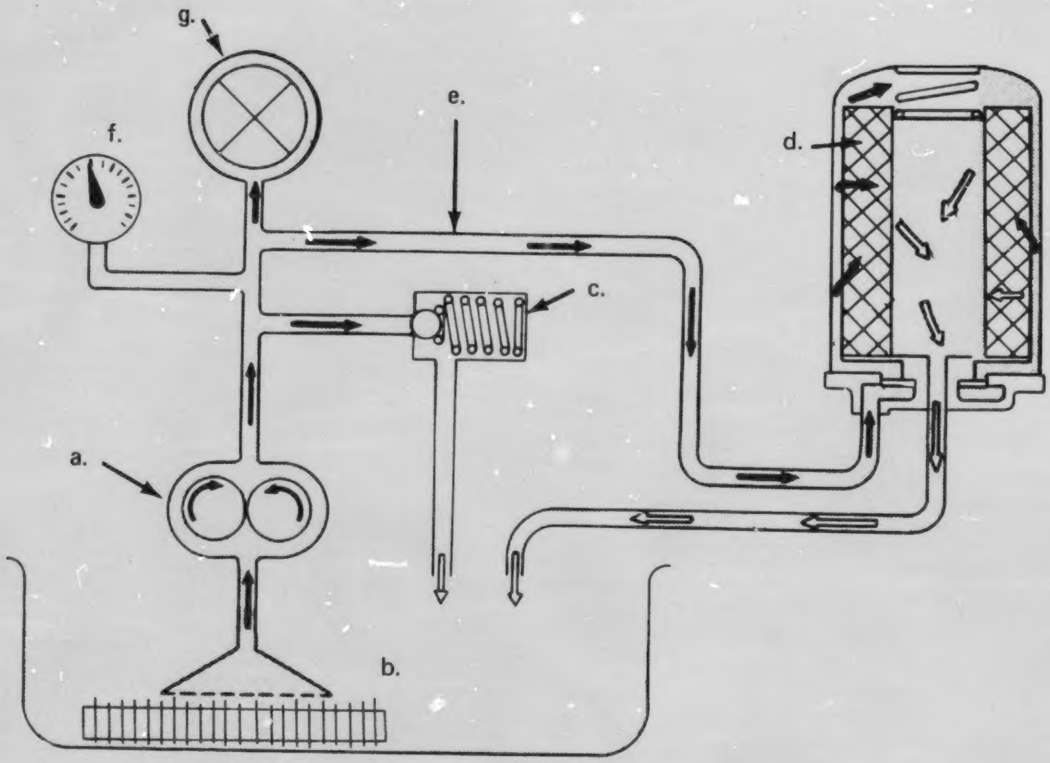
3. List three types of lubrication systems.

a. ____

b. ____

c. ____

4. Identify the components of the lubrication system.



a. ____________________ e. ____________________

b. ____________________ f. ____________________

c. ____________________ g. ____________________

d. ____________________

5. Match the components of the lubrication system on the right to their purposes.

_____a. Provides a reservoir for the engine oil

_____b. Limits the maximum oil pressure

_____c. Carry engine oil from one area to another

_____d. Indicates oil pressure during engine operation

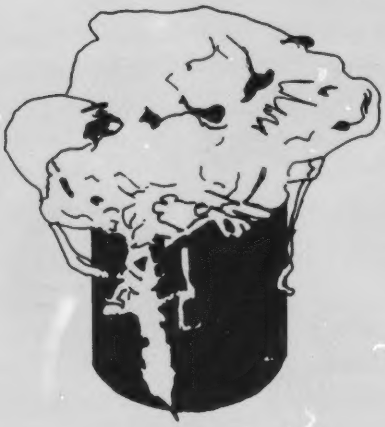
_____e. Forces oil under pressure to various parts of the engine for lubrication

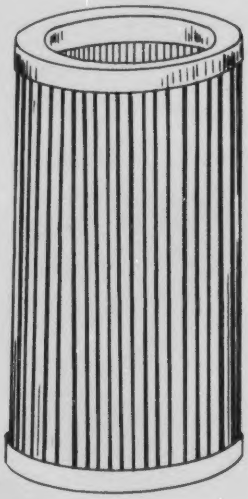
_____f. Strains the engine oil removing abrasive particles

_____g. Engine coolant flows through this and helps dissipate the heat in the engine oil

1. Oil galleries
2. Oil filter
3. Pressure regulating valve
4. Oil pump
5. Oil pan
6. Pressure gauge
7. Oil cooler

6. Identify two types of oil filters.





a. ______________________ b. ______________________

7. Name two types of oil pumps.

a. ____

b. ____

8. List five sources of oil contamination.

   a. ________________________________

   b. ________________________________

   c. ________________________________

   d. ________________________________

   e. ________________________________

9. List the purposes of lubricating valves.

   a. ________________________________

   b. ________________________________

10. Distinguish between internally and externally mounted oil coolers by placing an "X" next to the description of circulation in an internally mounted oil cooler.

    _____a. Both water and oil are pumped through the oil cooler

    _____b. Engine coolant is pumped by water pump through oil cooler mounted in the crankcase and back to the radiator where the heat is dissipated

11. Select true statements concerning mechanical and electrical oil pressure indicating systems by placing an "X" in the appropriate blanks.

    _____a. Mechanical-Bourdon tube gauge which tends to straighten out when pressure is applied

    _____b. Electrical

    1. Sending unit is at pressure source

    2. Indicating gauge is on control panel

12. Demonstrate the ability to:

    a. Check and adjust oil pressure on a live engine.

    b. Change an oil filter.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

LUBRICATION SYSTEMS
UNIT I

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 5
   d. 1
   e. 2

2. a. Reduces friction between moving parts
   b. Absorbs and dissipates heat
   c. Seals the piston rings and cylinder walls
   d. Cleans and flushes moving parts
   e. Helps deaden the noise of the engine

3. a. Circulating splash
   b. Internal force feed and splash
   c. Full internal force feed

4. a. Oil pump
   b. Oil pan
   c. Pressure regulating valve
   d. Oil filter
   e. Oil galleries
   f. Pressure gauge
   g. Engine bearings

5. a. 5
   b. 3
   c. 1
   d. 6
   e. 4
   f. 2
   g. 7

6. a. Depth filter--Cotton waste type
   b. Surface filter--Wire mesh type

7. Any two of the following:

   a. Gear
   b. Rotor
   c. Vane

8. Any five of the following:

   a. Storing and handling
   b. Dust form air that is breathed into engine
   c. Improper engine warm-up
   d. Antifreeze leaking into oil supply
   e. Oxidation
   f. Carbon particles
   g. Engine wear
   h. Fuel dilution

9. a. Regulate oil pressure
   b. Bypass oil at filters and oil coolers

10. b

11. a, b

12. Performance skills evaluated to the satisfaction of the instructor

COOLING SYSTEMS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to name two functions of the cooling system and identify the parts in a liquid cooling system. The student should also be able to reverse flush a radiator and test for exhaust gas leakage and air in cooling system. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the cooling system with the correct definitions.
2. Name two functions of the cooling system.
3. List effects of an engine running too hot.
4. List effects of an engine running too cold.
5. Identify the parts in a liquid cooling system.
6. Identify the parts in an air cooling system.
7. Identify two types of radiators.
8. Name two functions of the radiator cap.
9. Name three types of fans used in cooling systems.
10. Name types of fan control.
11. Name two types of temperature gauges.
12. List three purposes for using a coolant filter or conditioner in the cooling system.
13. Select functions of the thermostat.
14. Select types of thermostats.
15. Match corrective actions with the disadvantages of using water as a coolant.
16. Select common materials that may restrict radiator coolant flow.
17. Identify the primary parts of a water pump and fan.

18. Demonstrate the ability to:
    - a. Reverse flush a radiator.
    - b. Test thermostat action.
    - c. Test for exhaust gas leakage and air in cooling system.

COOLING SYSTEMS
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate water pump overhaul.

VIII. Have students list cost of replacement of their vehicles water pump.

IX. Have students trace coolant flow through their engine.

X. Have students define electrolysis.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Parts in a Liquid Cooling System
    2. TM 2--Parts in an Air Cooling System
    3. TM 3--Types of Radiators
    4. TM 4--Pressure Cap Operation
    5. TM 5--Fan Types
    6. TM 6-- Mechanical Temperature Gauge
    7. TM 7--Electrical Temperature Indicating Systems
    8. TM 8--Coolant Filter

9. TM 9--Operation of a Thermostat
10. TM 10--Types of Thermostats
11. TM 11--Water Pump and Fan

D. Job Sheets

1. Job Sheet #1--Reverse Flush a Radiator
2. Job Sheet #2--Test Thermostat Action
3. Job Sheet #3--Test for Exhaust Gas Leakage and Air in Cooling System

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Engines*. 5th ed. Moline, Illinois: Deere and Company, 1980.

B. Kates, Edgar J. and Luck, William E. *Diesel and High Compression Gas Engines*. 3rd ed. Chicago: American Technical Society, 1974.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

COOLING SYSTEMS
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Coolant--Liquid that circulates through the cooling system to transfer engine heat

   B. Thermostat--Heat operated valve that automatically maintains correct operating temperature

   C. Pressure cap--Radiator cap with pressure and vacuum valve

   D. Fan--Forces cooling air through radiator core to more quickly dissipate the heat

   E. Bimetallic--Two strips of dissimilar metal welded together, one of which expands more when heated than the other

   F. Inhibitor--Chemical which dissolves in water to form a rustproof film on the metal

   G. Aeration--Mixture of air and water

   H. Radiator shutters--Device over radiator to maintain temperature variations of coolant

   I. Radiator--Heat exchanger in which cooling water gives up heat to the air without coming into direct contact with it

   J. Temperature gauge--Unit in dash that monitors engine temperature

II. Functions of the cooling system

   A. Prevents engine overheating

   B. Regulates engine temperature

III. Effects of an engine running too hot

   A. Excessive wear

   B. Scoring

   C. Knock

   D. Burned piston and valves

   E. Lubrication failure

   F. Seizure of moving parts

   G. Loss of power

INFORMATION SHEET

IV. Effects of an engine running too cold

- A. Excessive wear
- B. Poor fuel economy
- C. Accumulation of water and sludge in the crankcase
- D. Loss of power

V. Parts in a liquid cooling system (Transparency 1)

- A. Radiator
- B. Fan drive belt
- C. Water pump
- D. Engine water jacket
- E. Thermostat
- F. Connecting hoses
- G. Liquid or coolant
- H. Pressure cap
- I. Bypass
- J. Fan
- K. Shutters and control
- L. Temperature sending unit

VI. Parts in an air cooling system (Transparency 2)

- A. Cylinder head
- B. Cylinder block
- C. Injection pump
- D. Injector nozzle
- E. Direct air-cooling system
- F. Aerodynamic intake system
- G. Combustion chamber

INFORMATION SHEET

VII. Types of radiators (Transparency 3)

A. Cellular type core

B. Tube and fin type core

VIII. Functions of the radiator cap (Transparency 4)

A. Allows atmospheric pressure to enter the cooling system

(NOTE: The vacuum valve opens.)

B. Prevents coolant from escaping at normal temperatures

(NOTE: The pressure valve permits escape of coolant or steam when pressure reaches a certain point. Pressure rise of one pound will raise the boiling temperature of water about 3 degrees fahrenheit.)

IX. Types of fans used in cooling systems (Transparency 5)

A. Suction type

B. Blower type

C. Reversible type

X. Types of fan control

A. Helical coil spring

B. Flex-blade fan

C. Electric auxillary control

XI. Types of temperature gauges (Transparencies 6 and 7)

A. Mechanical

B. Electrical

XII. Purposes of a coolant filter or conditioner (Transparency 8)

A. Softens the water

(NOTE: Chemicals in the filter element remove corrosives and keep the water jackets free of scale.)

B. Removes dirt

(NOTE: Filter element is replaceable and dirt which settles to bottom may be drained.)

C. Provides a place for rust inhibitors in the filter element

(NOTE: Rust inhibitors dissolve to form a rust proof film on the metal surfaces of the cooling system.)

INFORMATION SHEET

XIII. Functions of the thermostat (Transparency 9)

- A. Provides automatic control of the engine temperature
- B. Permits rapid engine warm-up when closed
- C. Permits efficient cooling when open

XIV. Types of thermostats (Transparency 10)

- A. Bellows
- B. Bimetallic
- C. Pellet

XV. Disadvantages of using water as a coolant and corrective actions

- A. Freezes readily when cold--Add antifreeze
- B. Boils and evaporates when hot--Pressurize system
- C. Corrodes metal parts--Add rust inhibitor
- D. Causes mineral deposits and scale in water jackets--Use soft water and chemical additives

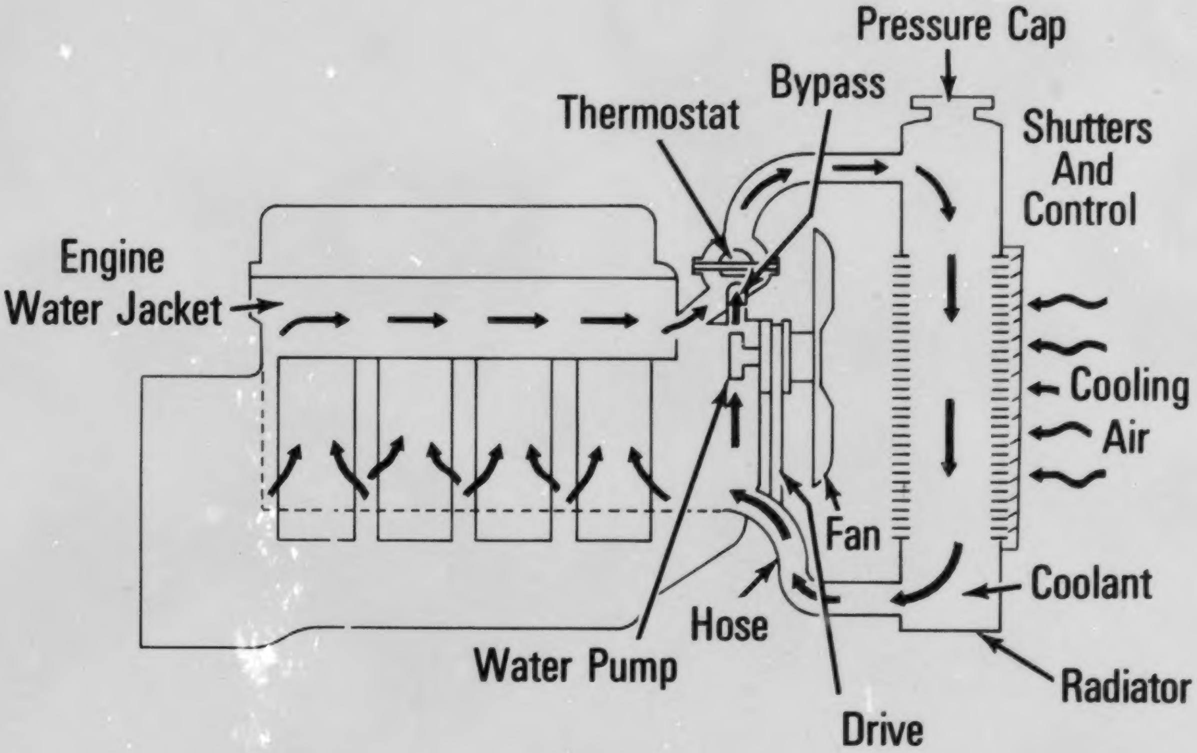
XVI. Materials that may restrict radiator coolant flow

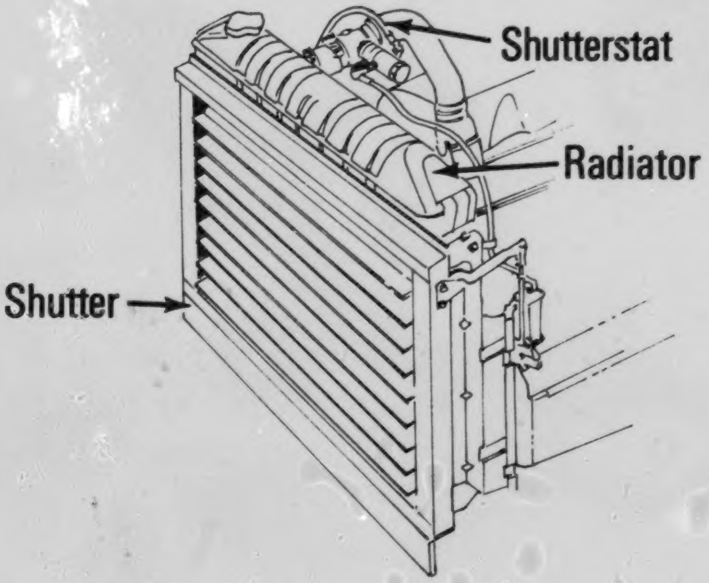
- A. Rust
- B. Scale
- C. Oil
- D. Lime

XVII. Primary parts of a water pump and fan (Transparency 11)

- A. Fan blade assembly
- B. Fan hub
- C. Fan belt
- D. Pulley
- E. Bearing and shaft assembly
- F. Water pump housing
- G. Impeller

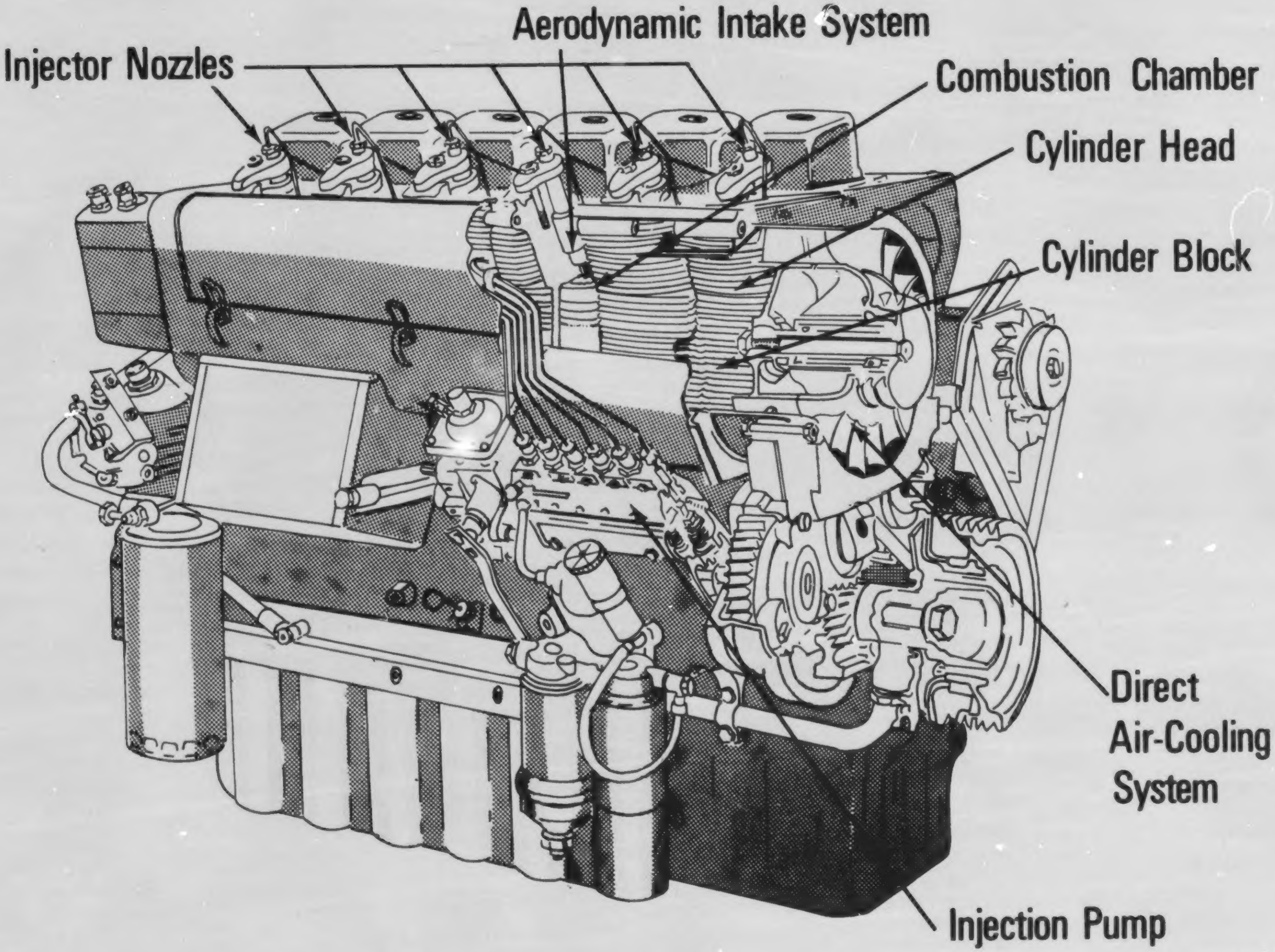
Parts In a Liquid Cooling System


Pressure Cap
Bypass
Thermostat
Shutters
And
Control
Engine
Water Jacket
Cooling
Air
Fan
Coolant
Hose
Water Pump
Radiator
Drive


Shutterstat
Radiator
Shutter

Typical Air Operated Shutter Assembly

Parts In an Air Cooling System


Aerodynamic Intake System
Injector Nozzles
Combustion Chamber
Cylinder Head
Cylinder Block
Direct Air-Cooling System
Injection Pump

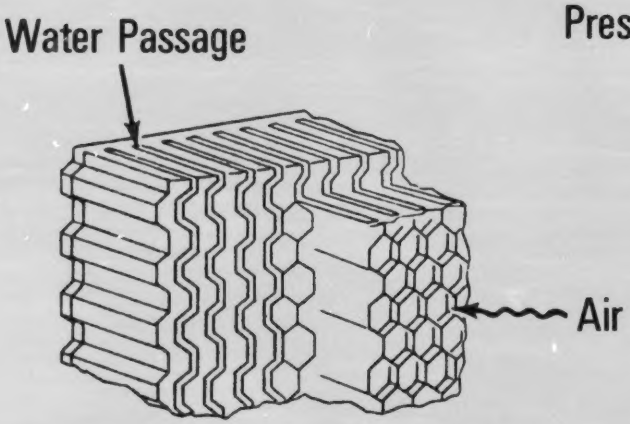
TM 2

686

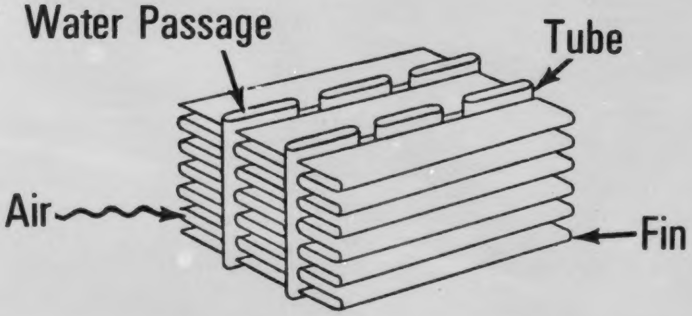
687

D:F - 55-D

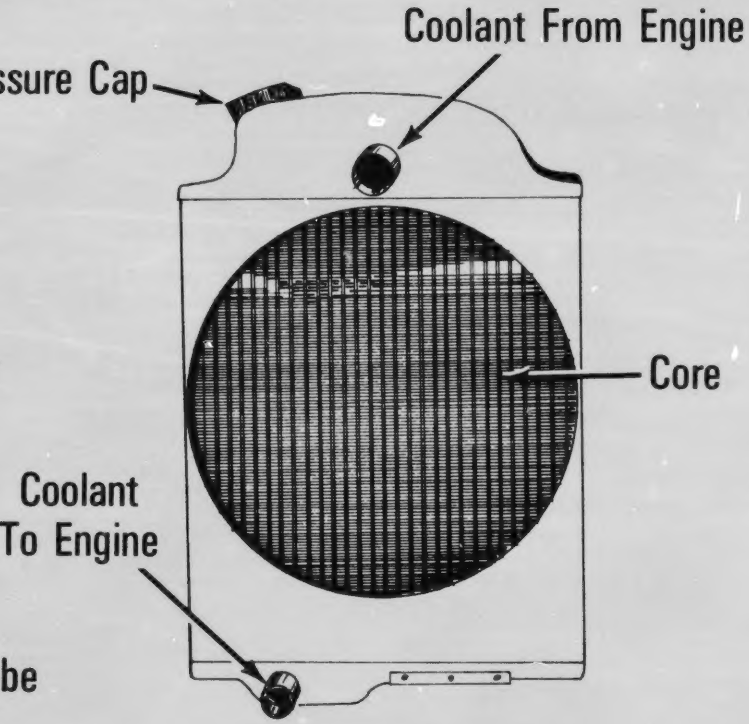
Types of Radiators


Water Passage
Air

Cellular Type Core Radiator


Water Passage
Tube
Air
Fin

Tube and Fin-Type Core Radiator


Coolant From Engine
Pressure Cap
Core
Coolant
To Engine

Typical Radiator

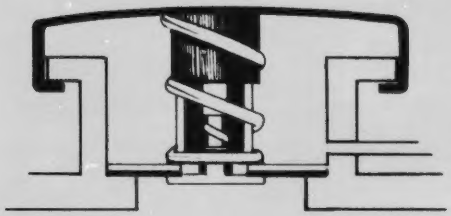
TM 3

688

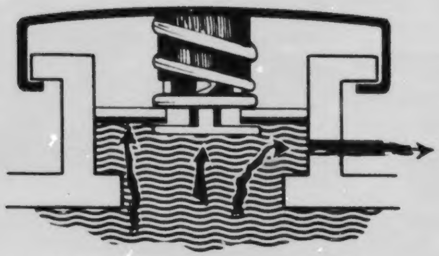
689

D:F - 57-D

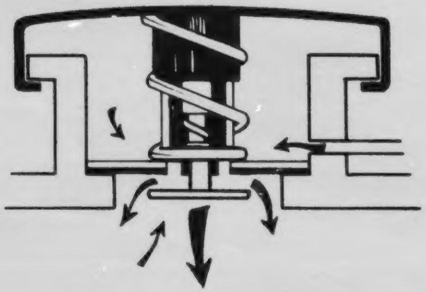
Pressure Cap Operation



Valves Closed

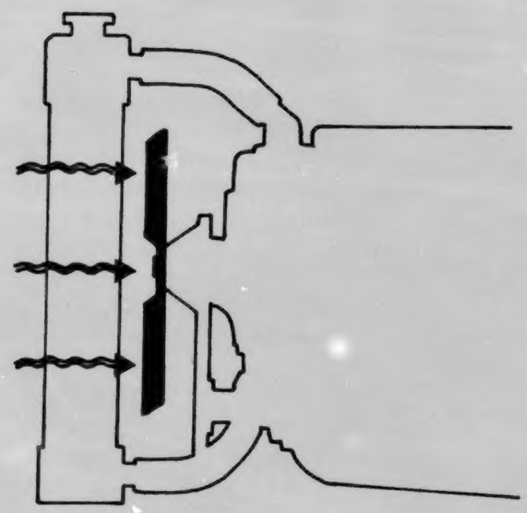


Pressure Valve Open

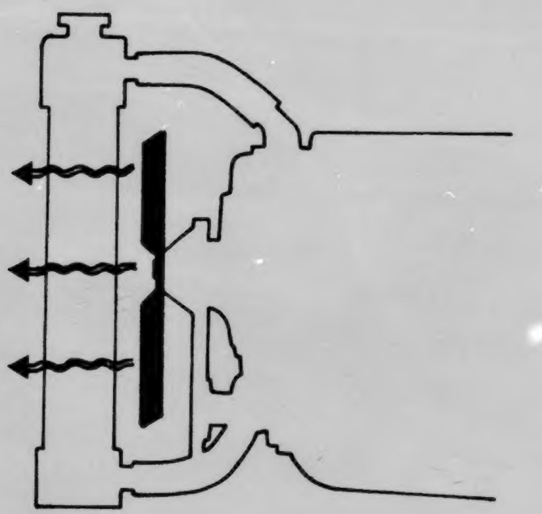


Vacuum Valve Open

Fan Types



Suction Fan



Blower Fan

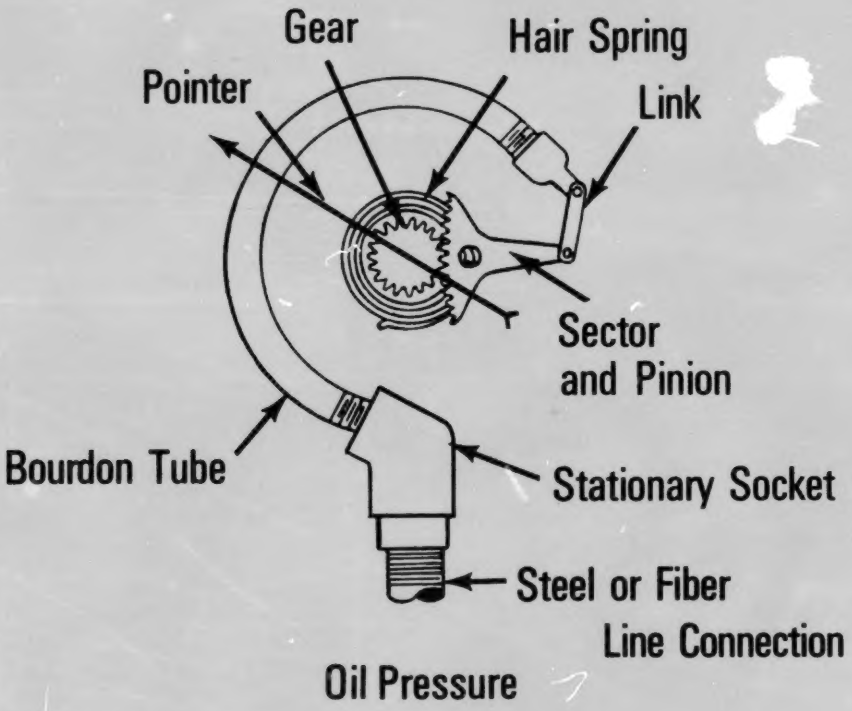
TM 5

692

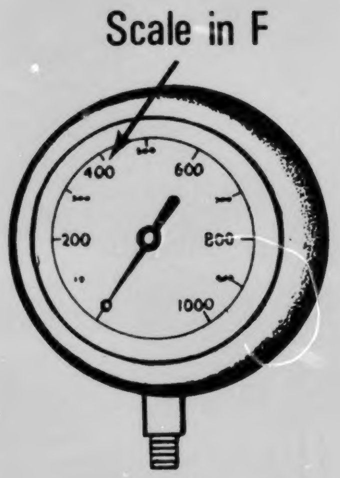
693

D:F · 61-D

Mechanical Temperature Gauge


Gear
Hair Spring
Pointer
Link
Sector and Pinion
Bourdon Tube
Stationary Socket
Steel or Fiber Line Connection
Oil Pressure

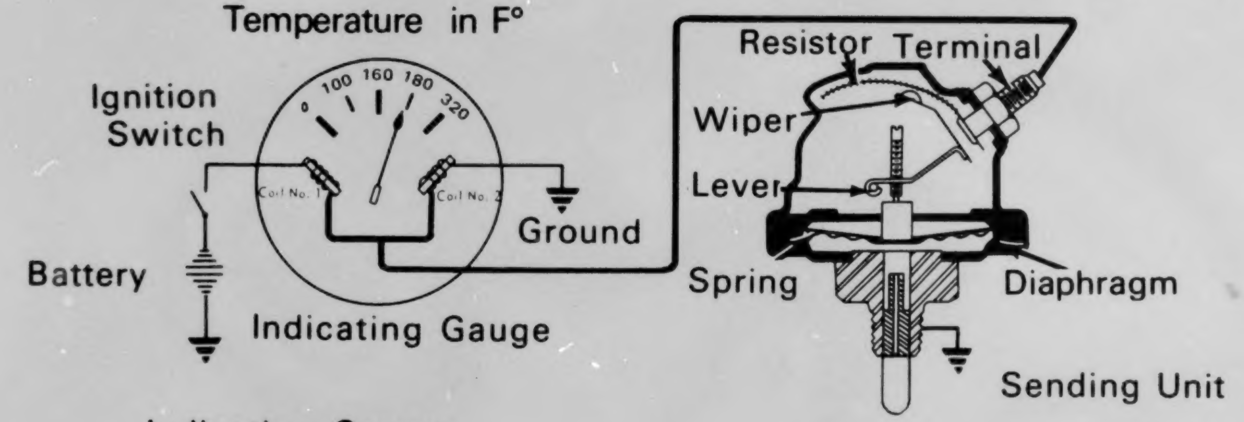
Bourdon Tube Gauge

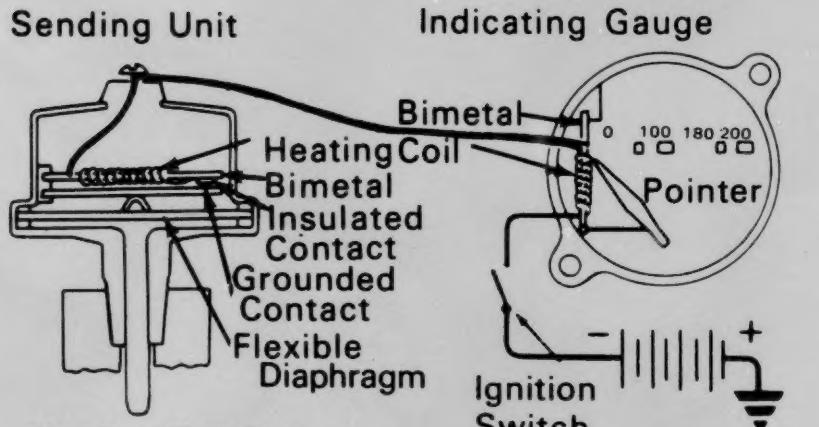

Scale in F
400
600
200
800
1000

Complete Gauge

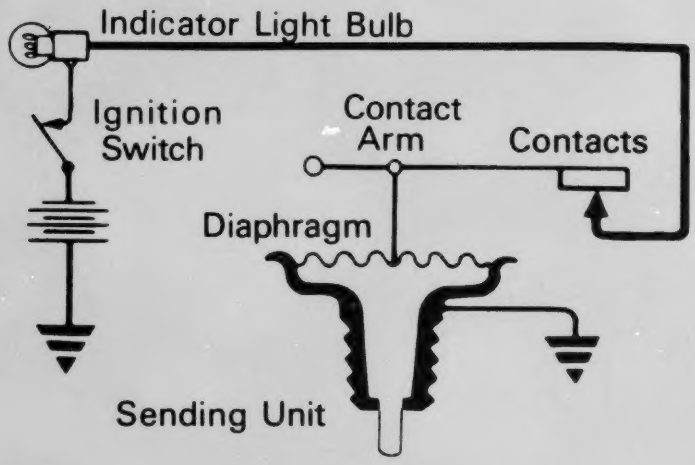
Electrical Temperature Indicating Systems

Electromagnetic Coil System for Indicating Coolant Temperature


Temperature in F°
Ignition Switch
0
100
160
180
320
Coil No. 1
Coil No. 2
Ground
Battery
Indicating Gauge
Resistor
Terminal
Wiper
Lever
Spring
Diaphragm
Sending Unit


Sending Unit
Indicating Gauge
Bimetal
Heating Coil
Bimetal
Insulated Contact
Grounded Contact
Flexible Diaphragm
0
100
180
200
Pointer
Ignition Switch
-
+

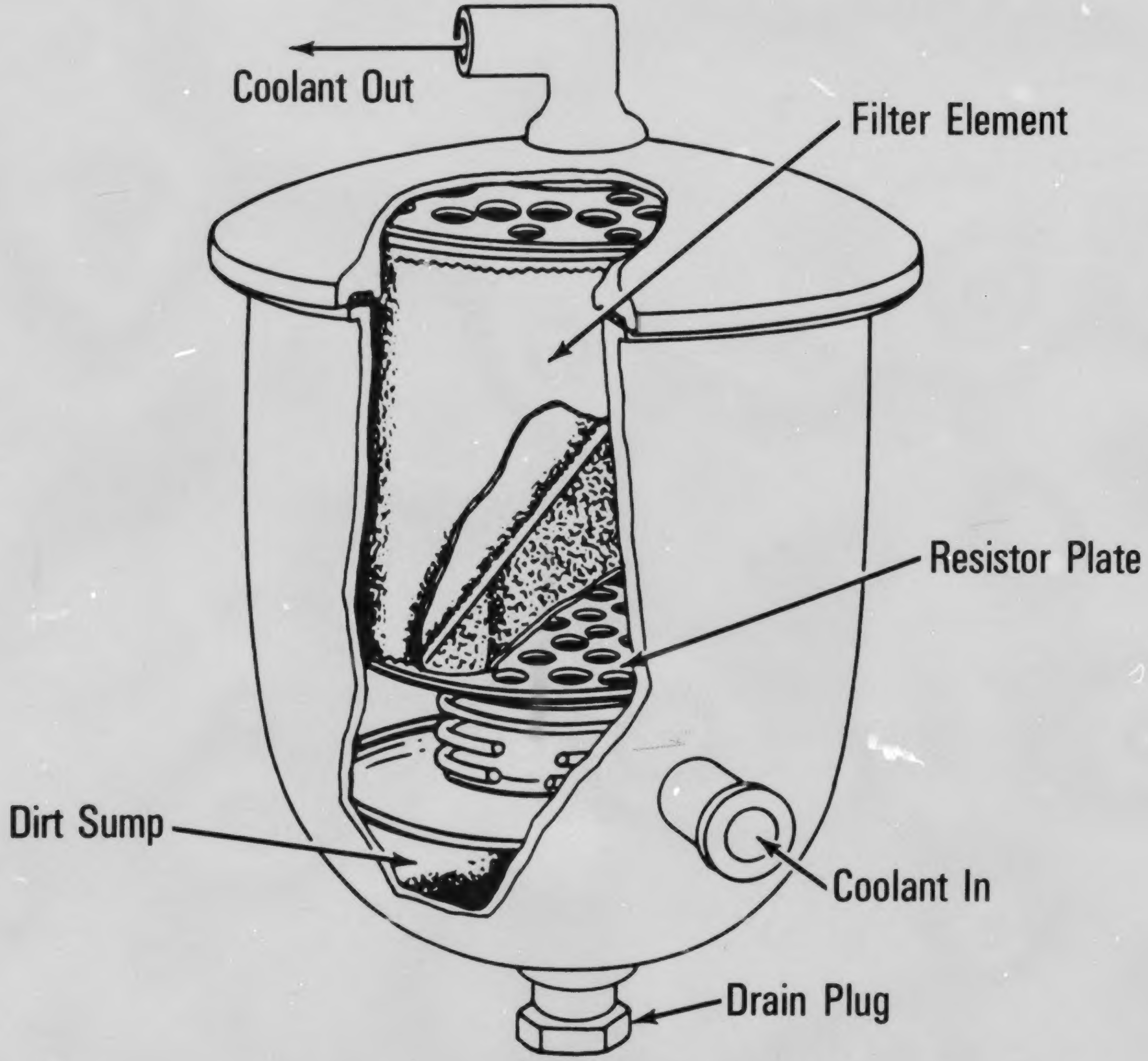
Heating Coil System


Indicator Light Bulb
Ignition Switch
Contact Arm
Contacts
Diaphragm
Sending Unit

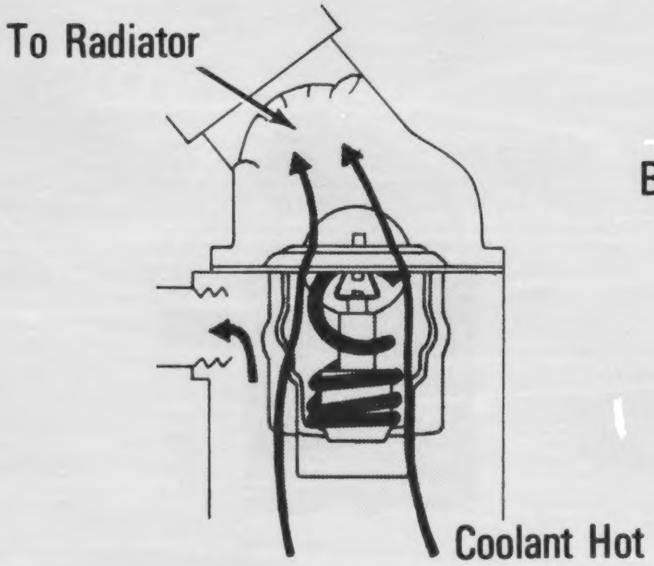
TM 7

D:F - 65-D

Coolant Filter

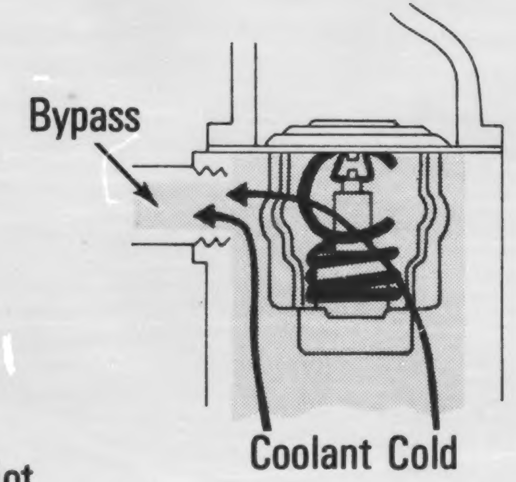

Coolant Out
Filter Element
Resistor Plate
Dirt Sump
Coolant In
Drain Plug

Operation of a Thermostat



To Radiator
Coolant Hot

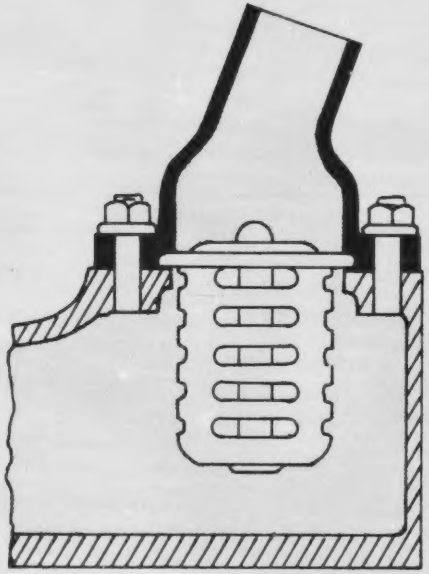
Thermostat Open



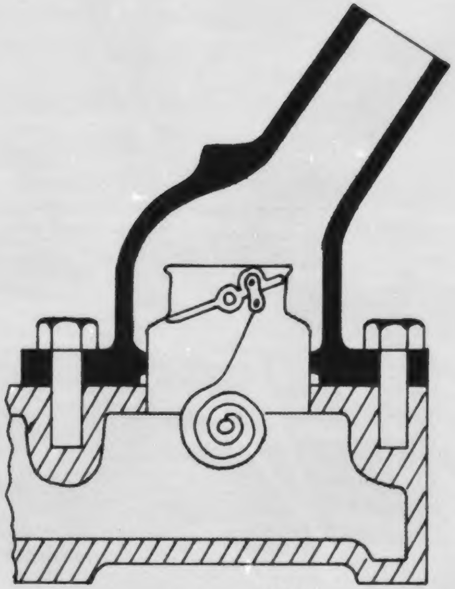
Bypass
Coolant Cold

Thermostat Closed

Types of Thermostats



Bellows Thermostat

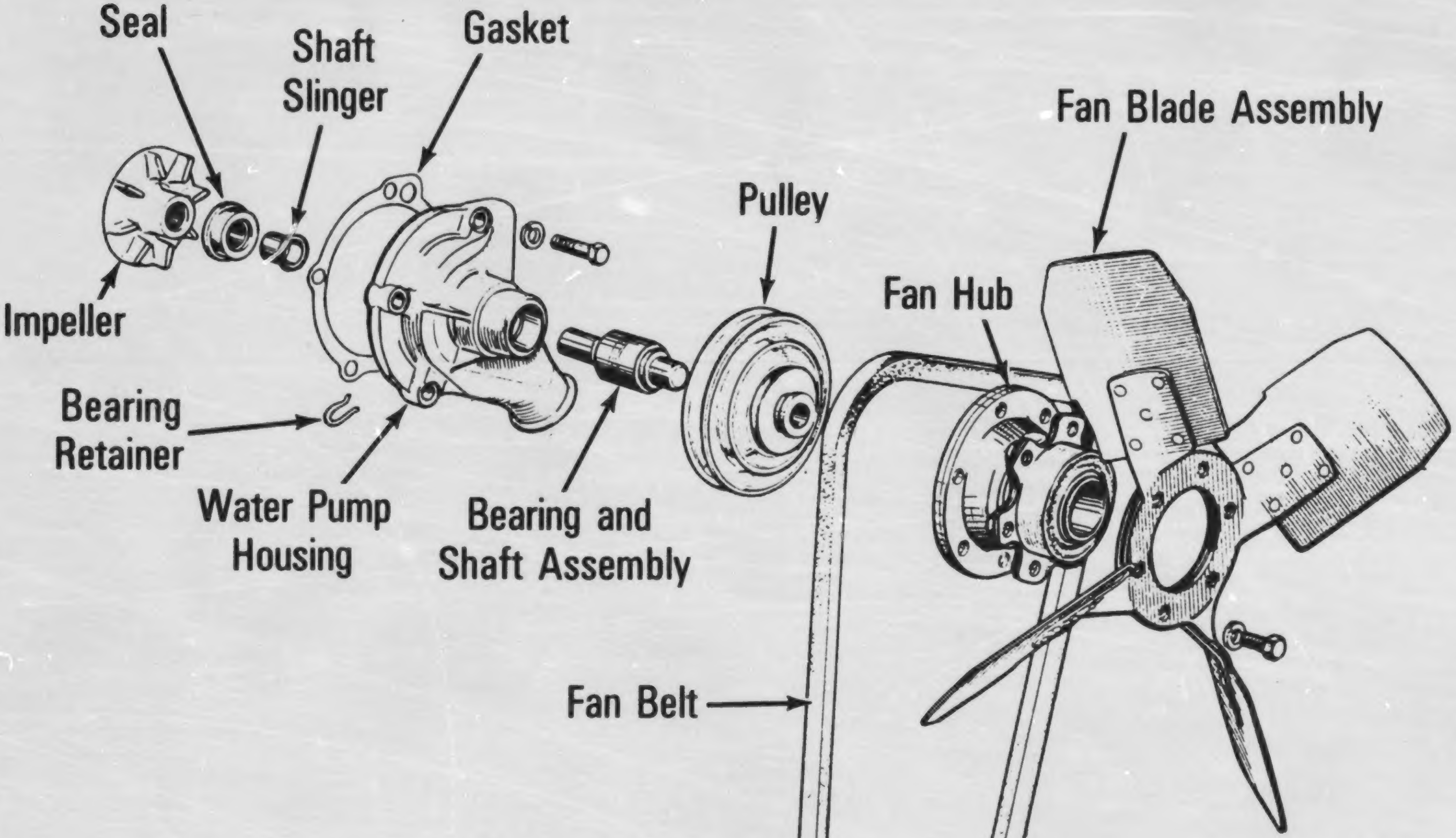


Bimetallic Thermostat

TM 10

D:F-71-D

Water Pump and Fan


Seal
Shaft Slinger
Gasket
Fan Blade Assembly
Pulley
Fan Hub
Impeller
Bearing Retainer
Water Pump Housing
Bearing and Shaft Assembly
Fan Belt

COOLING SYSTEMS
UNIT II

JOB SHEET #1--REVERSE FLUSH A RADIATOR

I. Tools and materials

A. Radiator

B. Appropriate service manual

C. Flushing gun

D. Hand tools

E. Water source

F. Compressed air source

G. Safety glasses

II. Procedure

(CAUTION: Follow all shop safety procedures.)

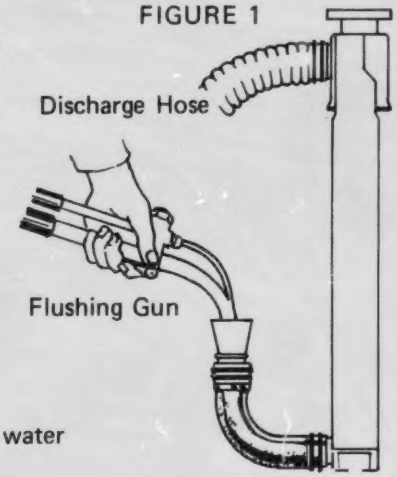
A. Drain the radiator

B. Disconnect both hoses

C. Connect the flushing gun hose to water source and air source of 100 PSI (pounds per square inch)

D. Connect the flushing gun nozzle to lower radiator hose (Figure 1)

FIGURE 1



E. Turn on water

JOB SHEET #1

F. Fill radiator

G. Inject air in short bursts to clear the tubes

H. Allow radiator to fill between bursts

I. Continue until water flows freely

COOLING SYSTEMS
UNIT II

JOB SHEET #2--TEST THERMOSTAT ACTION

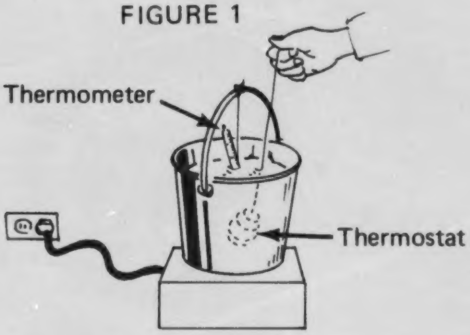
I. Tools and materials

- A. Heat source
- B. Container of water
- C. Thermometer
- D. Thermostat
- E. Safety glasses

II. Procedure

A. Suspend the thermostat and thermometer in container of water (Figure 1)

FIGURE 1



B. Compare the temperature rating stamped on the frame of thermostat to the thermometer

C. Thermostat should start to open at the temperature stamped on the frame and be fully open at 22°F above the specified temperature

D. Remove thermostat and observe its closing action

E. If thermostat is defective, discard

COOLING SYSTEMS
UNIT II

JOB SHEET #3--TEST FOR EXHAUST GAS LEAKAGE AND AIR IN COOLING SYSTEM

I. Tools and materials

A. Live engine

B. Appropriate service manual

C. Rubber tube

D. Bottle of water

E. Safety glasses

II. Procedure

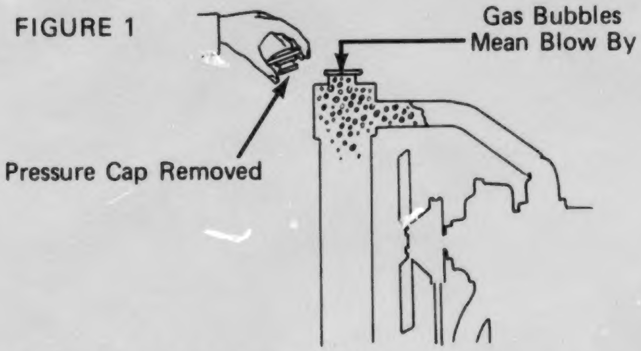
(CAUTION: Follow all shop safety procedures.)

A. Test for exhaust gas leakage (blow-by)

1. Warm up the engine and keep it under load

2. Remove the radiator cap and look for excessive bubbles in the coolant (Figure 1)

FIGURE 1



3. Look for a sign of blow-by such as bubbling or an oil film on the coolant

(NOTE: A cracked head or a loose cylinder head joint allows hot exhaust gas to be blown into the cooling system under combustion pressures, even though the joint may be tight enough to keep liquid from leaking into the cylinder. The cylinder head gasket itself may be burned and corroded by escaping exhaust gases. Exhaust gases dissolved in coolant destroy the inhibitors and form acids which cause corrosion, rust, and clogging.)

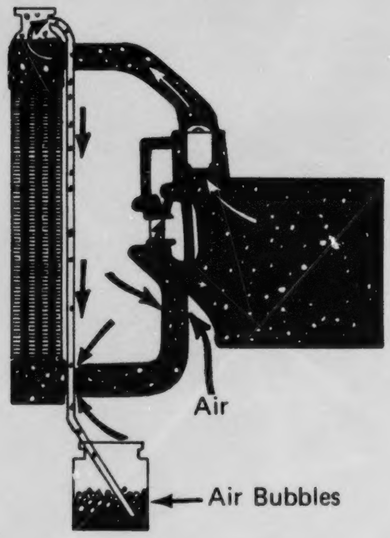
JOB SHEET #3

B. Test for air in cooling system

1. Adjust coolant to correct level
2. Replace pressure cap with a plain, air-tight cap
3. Attach rubber tube to lower end of overflow pipe

   (NOTE: Be sure radiator cap and tube are air tight.)
4. With transmission in neutral gear, run engine at high speed until temperature gauge stops rising and remains stationary
5. Without changing engine speed or temperature, put end of rubber tube in bottle of water
6. Watch for continuous stream of bubbles in the water bottle, showing that air is being drawn into the cooling system (Figure 2)

FIGURE 2



(NOTE: Air may be drawn into the coolant because of a leak in the system, turbulence in the top tank, or too-low coolant level.)

COOLING SYSTEMS
UNIT II

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Liquid that circulates through the cooling system to transfer engine heat

_____b. Heat operated valve that automatically maintains correct operating temperature

_____c. Radiator cap with pressure and vacuum valve

_____d. Forces air through radiator core to more quickly dissipate the heat

_____e. Two strips of dissimilar metal welded together, one of which expands more when heated than the other

_____f. Chemical which dissolves in water to form a rustproof film on the metal

_____g. Mixture of air and water

_____h. Device over radiator to maintain temperature variations of coolant

_____i. Heat exchanger in which cooling water gives up heat to the air without coming into direct contact with it

_____j. Unit in dash that monitors engine temperature

1. Inhibitor
2. Bimetallic
3. Radiator
4. Pressure cap
5. Coolant
6. Aeration
7. Thermostat
8. Radiator shutters
9. Fan
10. Temperature gauge

2. Name two functions of the cooling system.

a. ____

b. ____

3. List four effects of an engine running too hot.

a. ____

b. ____

c. ____

d. ____

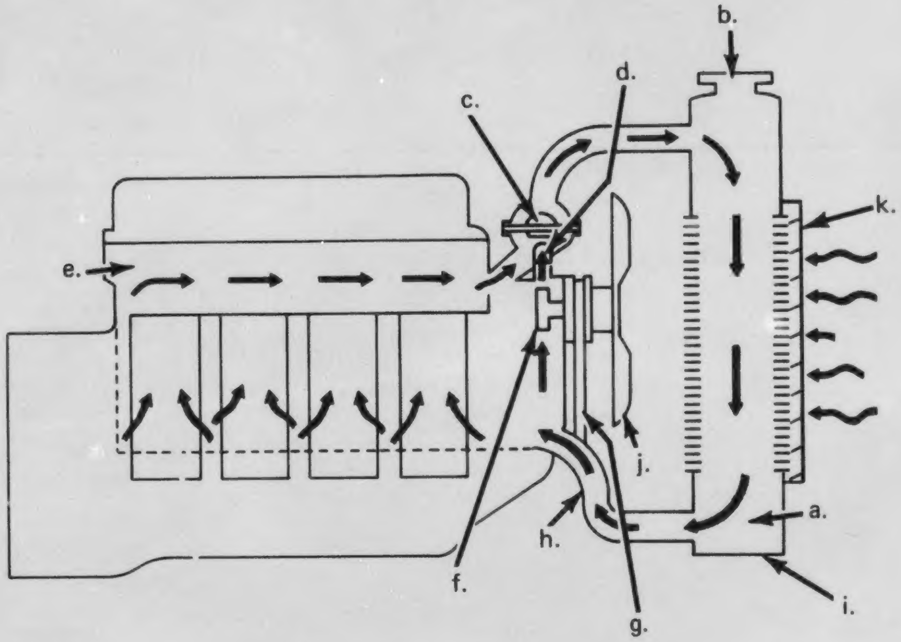
4. List three effects of an engine running too cold.

a. ____________________

b. ____________________

c. ____________________

5. Identify the parts in a liquid cooling system.



a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

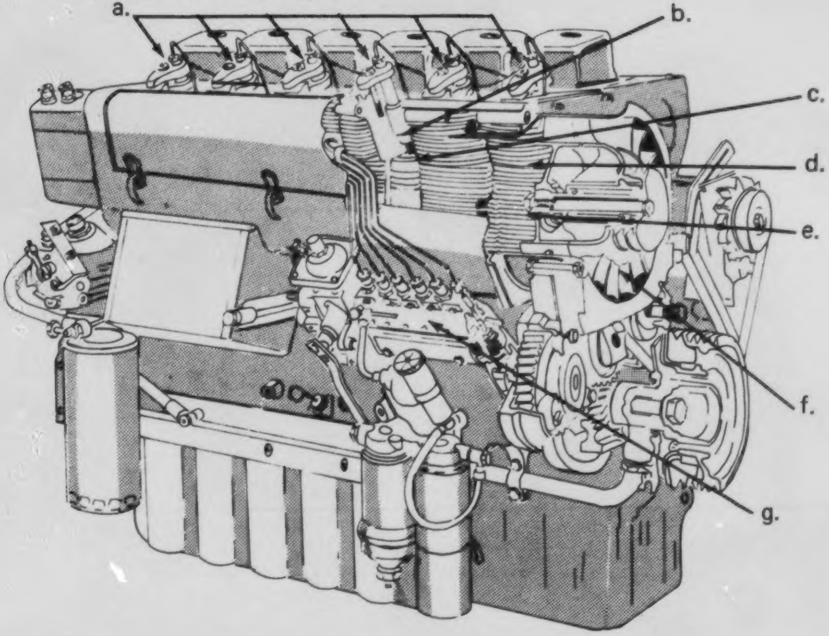
h. ____________________

i. ____________________

j. ____________________

k. ____________________

6. Identify the parts in an air cooling system.



a. ______________________________

b. ______________________________

c. ______________________________

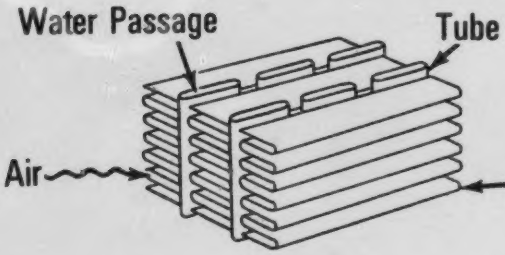
d. ______________________________

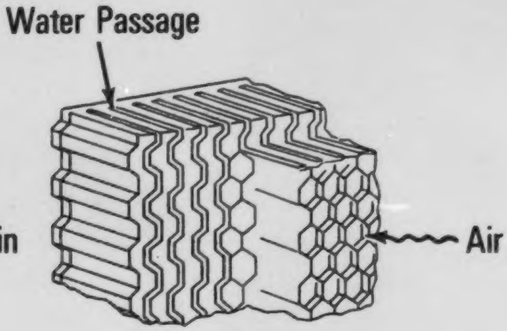
e. ______________________________

f. ______________________________

g. ______________________________

7. Identify two types of radiators.


Water Passage
Tube
Air
Fin


Water Passage
Air

a. ______________________ b. ______________________

8. Name two functions of the radiator cap.

a. ____________________

b. ____________________

9. Name three types of fans used in cooling systems.

a. ____________________

b. ____________________

c. ____________________

10. Name two types of fan control.

a. ____________________

b. ____________________

11. Name two types of temperature gauges.

a. ____________________

b. ____________________

12. List three purposes for using a coolant filter or conditioner in the cooling system.

a. ____________________

b. ____________________

c. ____________________

13. Select functions of the thermostat by placing an "X" in the appropriate blanks.

_____ a. Permits rapid engine warm-up when closed

_____ b. Permits efficient cooling when open

_____ c. Permits rapid engine warm-up when open

_____ d. Permits efficient cooling when closed

_____ e. Provides automatic control of the engine temperature

14. Select the types of thermostats by placing an "X" in the appropriate blanks.

_____ a. Burrows

_____ b. Rectangular

_____ c. Bellows

_____ d. Bimetallic

_____ e. Pellet

15. Match the corrective actions on the right with the disadvantages of using water as a coolant.

_____a. Freezes readily when cold

_____b. Causes mineral deposits and scale in water jackets

_____c. Boils and evaporates when hot

_____d. Corrodes metal parts

1. Add rust inhibitor
2. Add antifreeze
3. Pressurize system
4. Use soft water and chemical additives

16. Select common materials that may restrict radiator coolant flow by placing an "X" in the appropriate blanks.

_____a. Oil

_____b. Hair

_____c. Suds

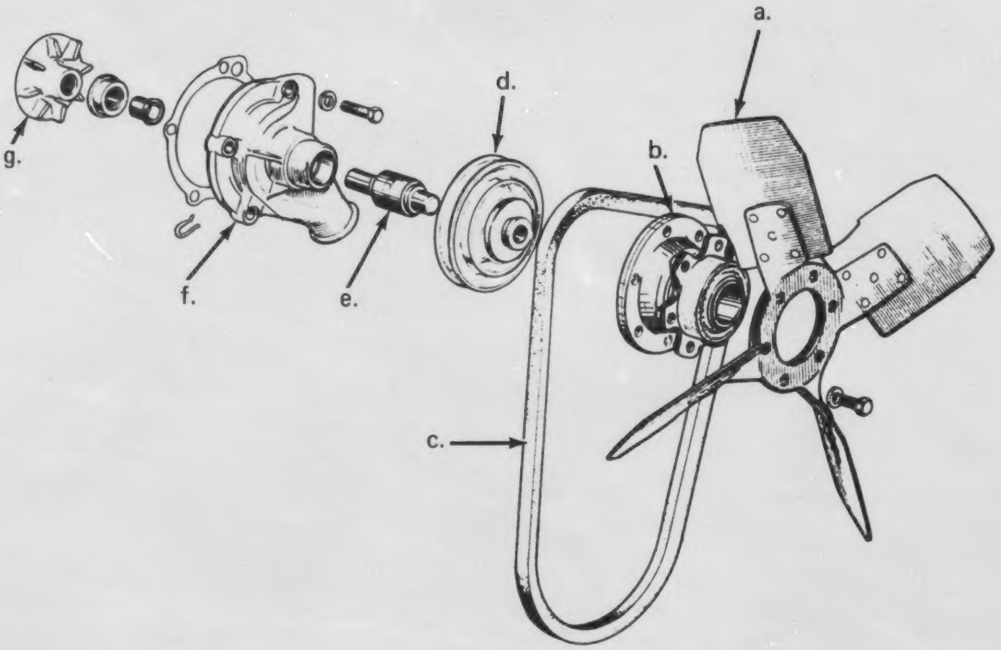
_____d. Lime

_____e. Scale

_____f. Mud

_____g. Rust

17. Identify the primary parts of a water pump and fan.



a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

18. Demonstrate the ability to:

    a. Reverse flush a radiator.

    b. Test thermostat action.

    c. Test for exhaust gas leakage and air in cooling system.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

COOLING SYSTEMS
UNIT II

ANSWERS TO TEST

1. a. 5
   b. 7
   c. 4
   d. 9
   e. 2
   f. 1
   g. 6
   h. 8
   i. 3
   j. 10

2. a. Prevents engine overheating
   b. Regulates engine temperature

3. Any four of the following:

   a. Excessive wear
   b. Scoring
   c. Knock
   d. Burned piston and valves
   e. Lubrication failure
   f. Seizure of moving parts
   g. Loss of power

4. Any three of the following:

   a. Excessive wear
   b. Poor fuel economy
   c. Accumulation of water and sludge in the crankcase
   d. Loss of power

5. a. Liquid or coolant
   b. Pressure cap
   c. Thermostat
   d. Bypass
   e. Engine water jacket
   f. Water pump
   g. Fan drive belt
   h. Connecting hoses
   i. Radiator
   j. Fan
   k. Shutters and control

6. a. Injector nozzles
   b. Aerodynamic intake system
   c. Combustion chamber
   d. Cylinder head
   e. Cylinder block
   f. Direct air-cooling system
   g. Injection pump

7. a. Tube and fin type core radiator
   b. Cellular type core radiator

8. a. Allows atmospheric pressure to enter the cooling system
   b. Prevents coolant from escaping at normal temperatures

9. a. Suction type
   b. Blower type
   c. Reversible type

10. Any two of the following:

    a. Helical coil spring
    b. Flex-blade fan
    c. Electric auxillary control

11. a. Mechanical
    b. Electrical

12. a. Softens the water
    b. Removes dirt
    c. Provides a place for rust inhibitors in the filter element

13. a, b, e

14. c, d, e

15. a. 2
    b. 4
    c. 3
    d. 1

16. a, d, e, g

17. a. Fan blade assembly
    b. Fan hub
    c. Fan belt
    d. Pulley
    e. Bearing and shaft assembly
    f. Water pump housing
    g. Impeller

18. Performance skills evaluated to the satisfaction of the instructor

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components of an air intake and exhaust system. The student should also be able to disassemble, inspect, and assemble a roots-type blower. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with air intake and exhaust systems with the correct definitions.
2. Name parts of an air intake system.
3. Name parts of an exhaust system.
4. Match types of air cleaners with their processes.
5. Complete a list of statements concerning methods of scavenging the cylinders on a two-stroke cycle engine.
6. Distinguish between port scavenging and valve scavenging in two-cycle engines.
7. Distinguish between positive displacement and centrifugal superchargers.
8. List advantages of a turbocharged engine.
9. Demonstrate the ability to:
    a. Test an engine for air flow restriction.
    b. Inspect a turbocharger for satisfactory operation.
    c. Remove, disassemble, service, assemble, and install a turbocharger.
    d. Disassemble a roots-type blower.
    e. Inspect a roots-type blower.
    f. Assemble a roots-type blower.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Make a display of different turbochargers.

VIII. Show film on dust effects.

IX. Have students make a list of weather effects on engine filtration systems.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  - A. Objective sheet
  - B. Information sheet
  - C. Transparency masters
    1. TM 1--Dry Type Air Cleaner
    2. TM 2--Viscous-Impingement Air Cleaner
    3. TM 3--Oil Bath Air Cleaner
    4. TM 4--Crankcase Scavenging Engine
    5. TM 5--Scavenging Pump and Blower
    6. TM 6--Port-Scavenged Engine
    7. TM 7--Valve-Scavenged Engine
    8. TM 8--Positive Displacement Supercharger
    9. TM 9--Centrifugal-Type Supercharger

D. Job sheets

1. Job Sheet #1--Test an Engine for Air Flow Restriction
2. Job Sheet #2--Inspect a Turbocharger for Satisfactory Operation
3. Job Sheet #3--Remove, Disassemble, Service, Assemble, and Install a Turbocharger
4. Job Sheet #4--Disassemble a Roots-Type Blower
5. Job Sheet #5--Inspect a Roots-Type Blower
6. Job Sheet #6--Assemble a Roots-Type Blower

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* 3rd ed. Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines.* 5th ed. Moline, Illinois: Deere and Company, 1980.

C. *V-71 Service Manual.* Detroit, Michigan: Detroit Diesel Allison, Revised 1975.

D. *H and NH Series Shop Manual.* Columbus, Indiana: Cummins Engine Co., Inc.

E. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

INFORMATION SHEET

I. Terms and definitions

  A. Filter--Unit containing an element of varying degrees of fineness to trap foreign particles

  B. Scavenging--Method of pushing air out of the cylinders during the exhaust stroke on two-cycle engines

  C. Port--Opening in a cylinder block or liner for intake and/or exhaust air on two-cycle engines

  D. Valve--Device for sealing the intake and/or exhaust ports in a cylinder head

  E. Blower--Method of increasing air pressure and velocity

  F. Roots-type blower--Positive displacement blower to raise intake air above atmospheric pressure

  G. Turbocharger--Exhaust-driven turbine which drives a centrifugal compressor

  H. Manifold--Pipe or casting with multiple openings to connect multiple cylinders to one outlet or inlet

  I. Supercharging--Method of charging cylinders with fresh air above atmospheric pressure on the intake stroke

  J. Naturally aspirated--Engine which is not supercharged

  K. Precleaner--Device to collect some dirt from air before it enters the main air cleaner

  L. Inter cooler--Intake manifold cooled by circulated water

  M. After cooler--A device used on turbocharged engines to cool air which has undergone compression

II. Parts of an intake system

  A. Precleaner, air cleaner

  B. Supercharger (if used)

  C. Intake manifold

  D. Piping

  E. Intake valves or ports

INFORMATION SHEET

III. Parts of an exhaust system

- A. Ports and/or valves
- B. Exhaust manifold
- C. Piping
- D. Muffler
- E. Turbocharger (if used)

IV. Types of air cleaners

- A. Dry element type--Cleaning is done by replacing element (Transparency 1)
- B. Viscous-impingement type--Cleans air by passing it through a maze of metal wool, wire, or screens saturated with oil (Transparency 2)
- C. Wet type--Cleans air by directing it through a center tube into the inner oil cup where direction of air flow is reversed causing most of the dirt to become trapped by the oil and settle in the sump (Transparency 3)

V. Methods of scavenging the cylinders

- A. Crankcase (Transparency 4)
    1. Air enters the engine through the crankcase
    2. Each downward movement of the piston compresses the vapor within the crankcase until the intake port or valve opens
    3. The compressed vapor escapes into the cylinder at a pressure nearly equal to atmospheric pressure
- B. Power piston (Transparency 5)
    1. Uses a separate piston and cylinder driven by the engine crankshaft
    2. Pushes the vapor into the cylinder as the intake valve or port opens
- C. Blower (Transparency 5)
    1. Uses a positive-displacement rotary blower driven by the engine
    2. Compresses the vapor into an air chamber surrounding the intake ports

INFORMATION SHEET

VI. Port and valve scavenging

A. Port scavenging--Air enters and gas leaves through ports in the cylinder block or liner which the piston uncovers (Transparency 6)

B. Valve scavenging--Air enters through ports in the cylinder block and gases leave through valves in the cylinder head (Transparency 7)

(NOTE: The scavenging process in the two-cycle engines uses a swish of air to push out the spent gases and replace them with fresh air at atmospheric pressure.)

VII. Types of superchargers

A. Positive displacement (Transparency 8)

(NOTE: The roots-type blower is a positive-displacement supercharger.)

1. Driven by a chain, belt, or gear

2. Resembles oil pumps in design

B. Centrifugal (Transparency 9)

(NOTE: Turbochargers are exhaust driven centrifugal type superchargers.)

1. Driven by engine, engine exhaust, or separate motor

2. Impeller normally moves thirty times engine speed

VIII. Advantages of a turbocharged engine

A. Increases horsepower output of a given displacement engine

B. Reduces weight by delivering more horsepower per pound than nonturbocharged engines

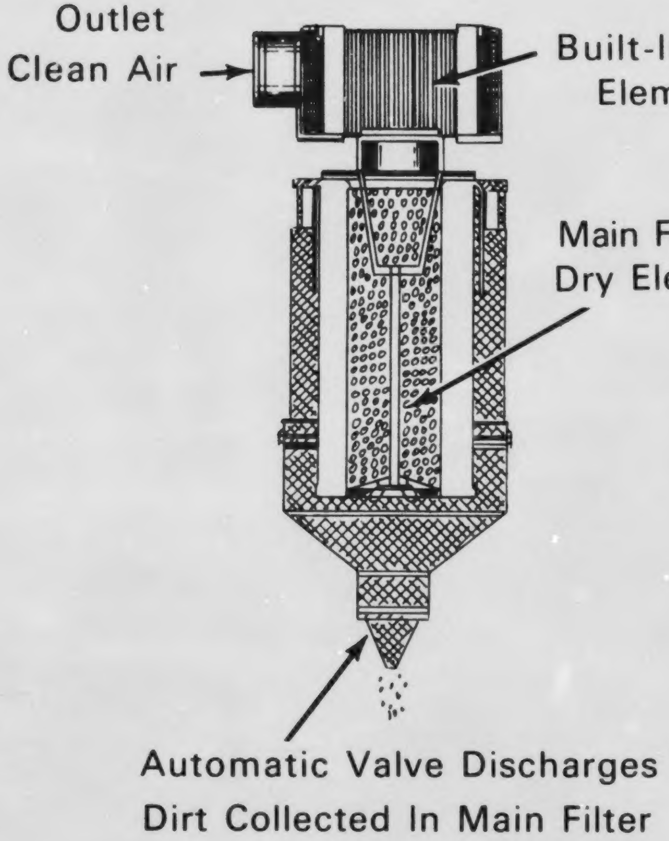
C. Cost of a turbocharged engine is less on a dollar per horsepower basis

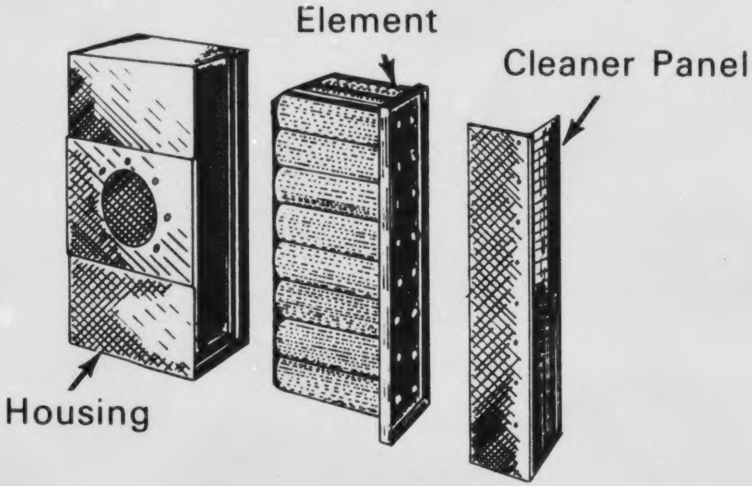
D. Maintains horsepower at higher altitudes

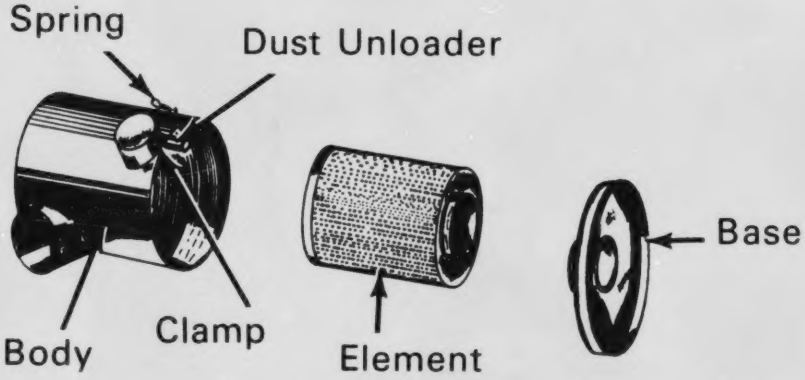
(NOTE: Naturally aspirated engines lose three percent of horsepower per each 1000 feet of altitude.)

E. Reduces exhaust smoke by supplying excess air to reduce exhaust density

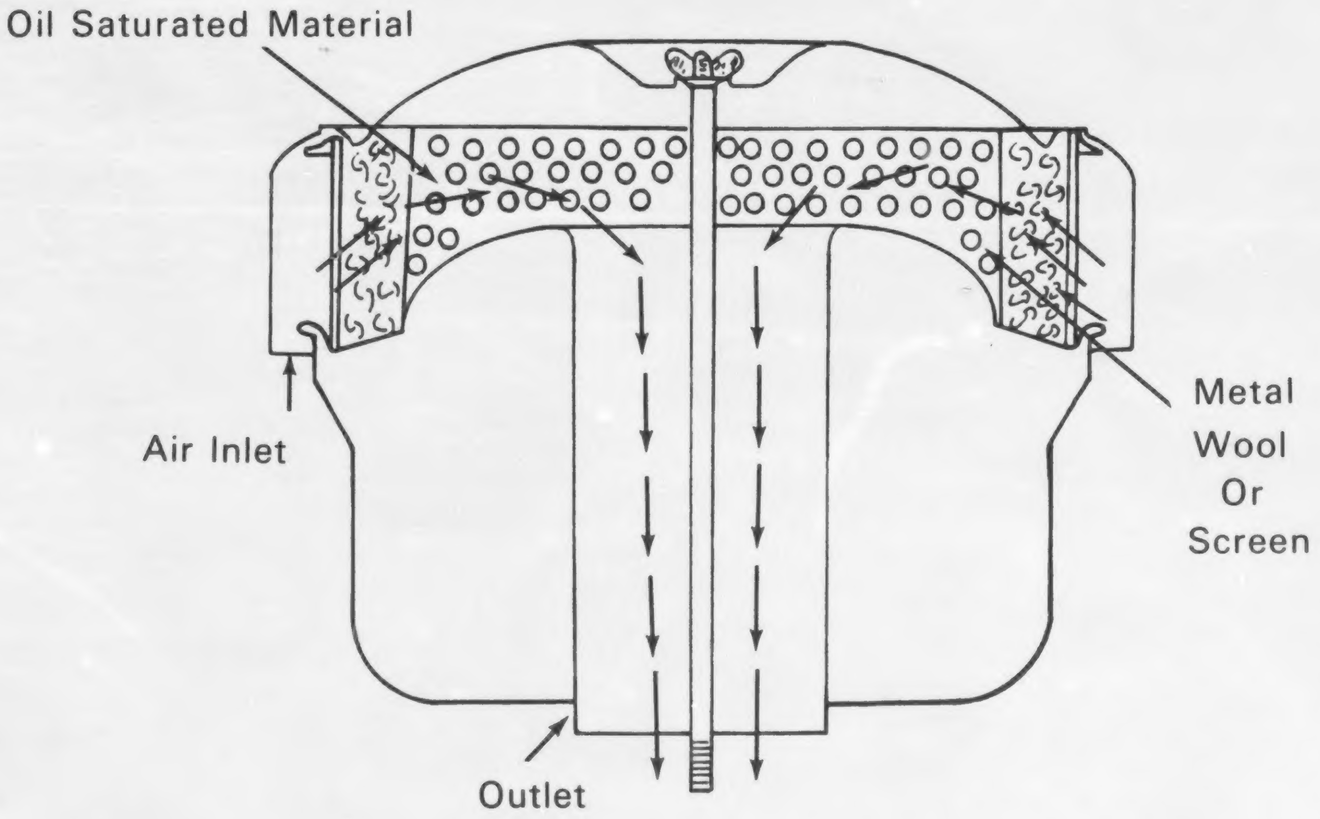
Dry Type Air Cleaner


Outlet
Clean Air
Built-In Safety Element
Main Fibrous Dry Element
Automatic Valve Discharges Dirt Collected In Main Filter

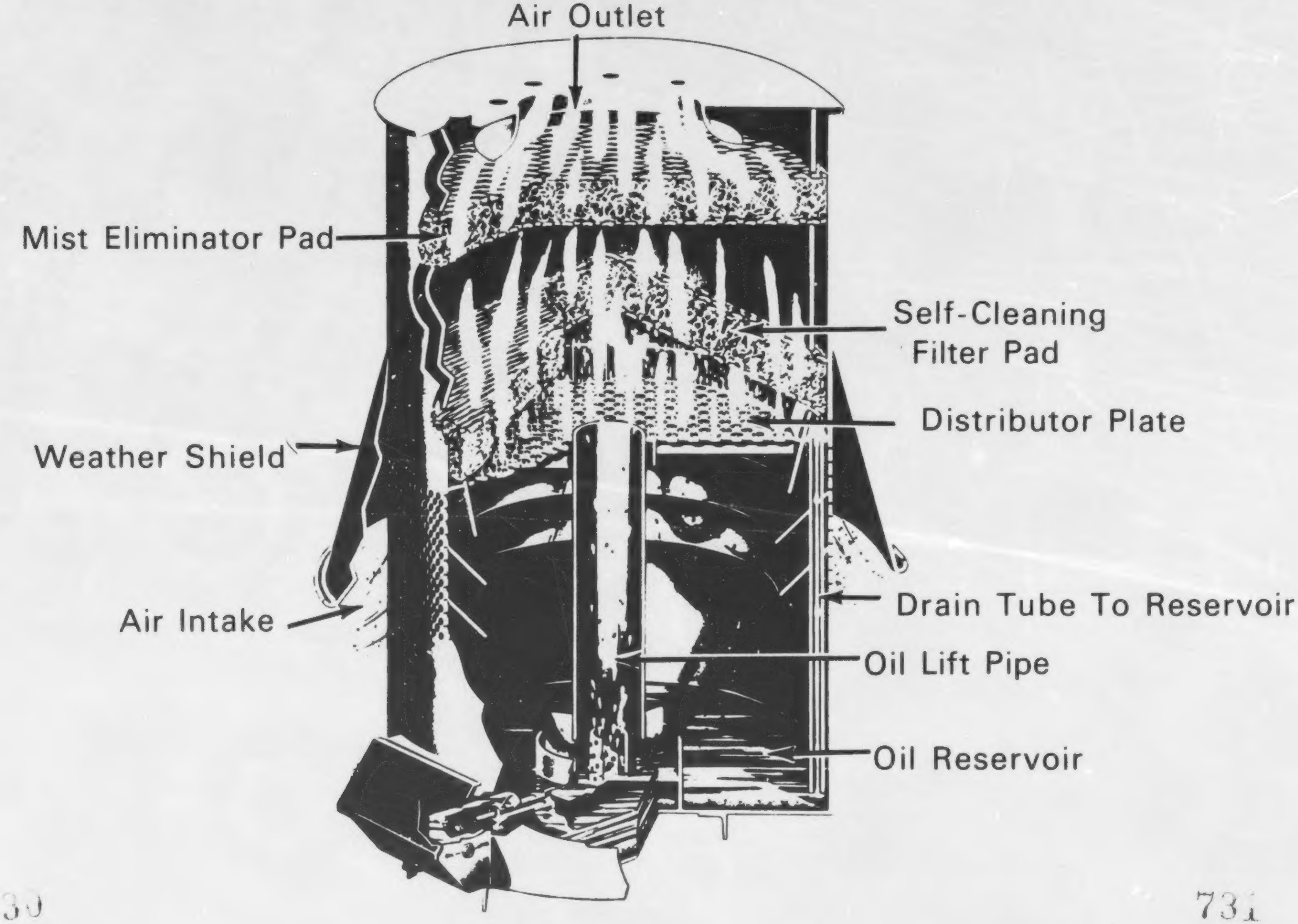

Element
Cleaner Panel
Housing


Spring
Dust Unloader
Base
Body
Clamp
Element

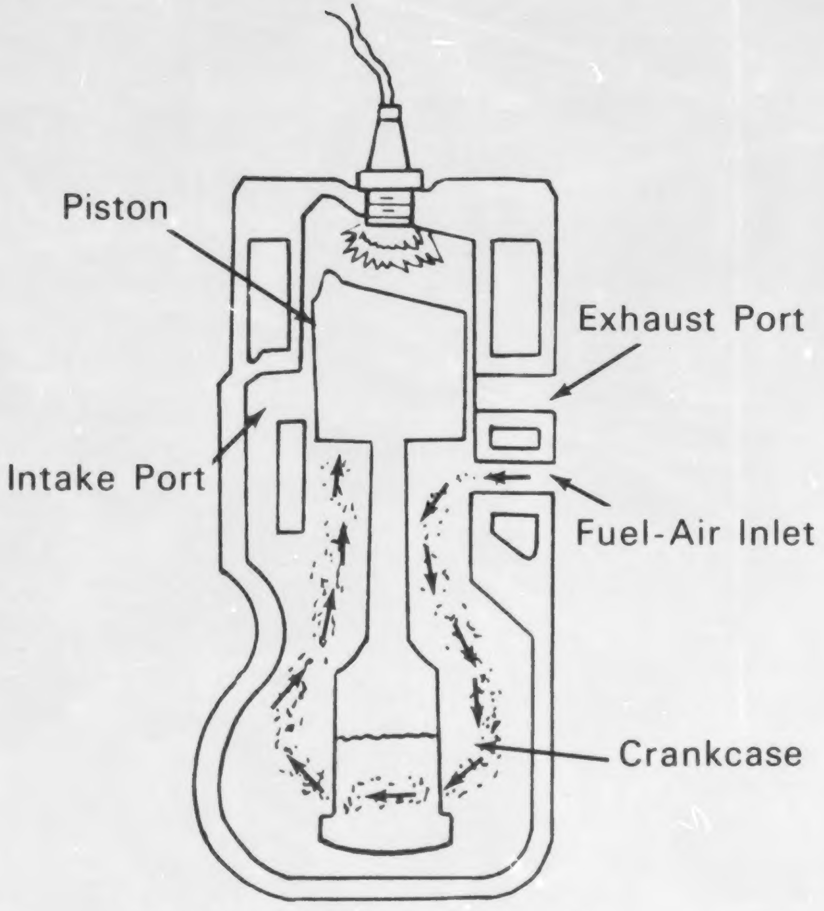
Viscous-Impingement Air Cleaner


Oil Saturated Material
Air Inlet
Metal Wool Or Screen
Outlet

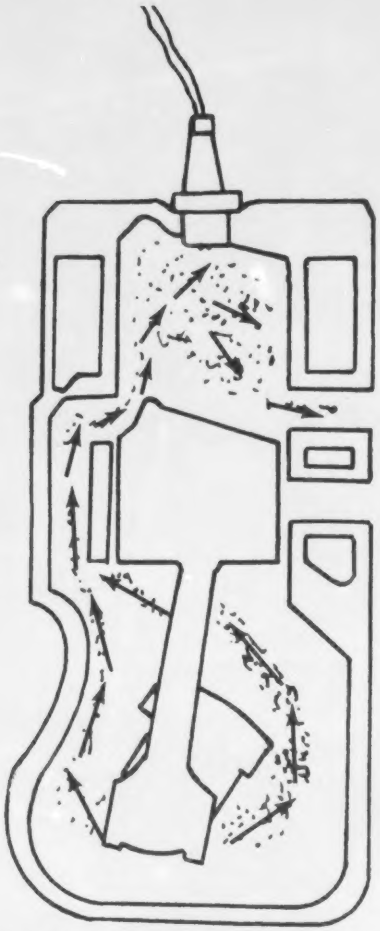
Oil Bath Air Cleaner


Air Outlet
Mist Eliminator Pad
Self-Cleaning Filter Pad
Distributor Plate
Weather Shield
Drain Tube To Reservoir
Air Intake
Oil Lift Pipe
Oil Reservoir

Crankcase Scavenging Engine


Piston
Exhaust Port
Intake Port
Fuel-Air Inlet
Crankcase

Compression/Power Stroke



Intake/Exhaust Stroke

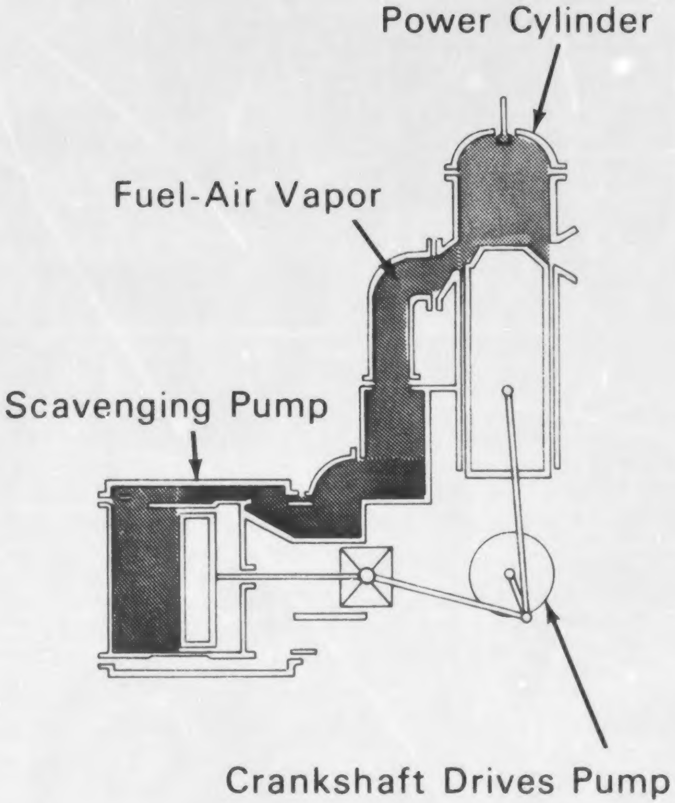
TM 4

D:F - 105-D

732

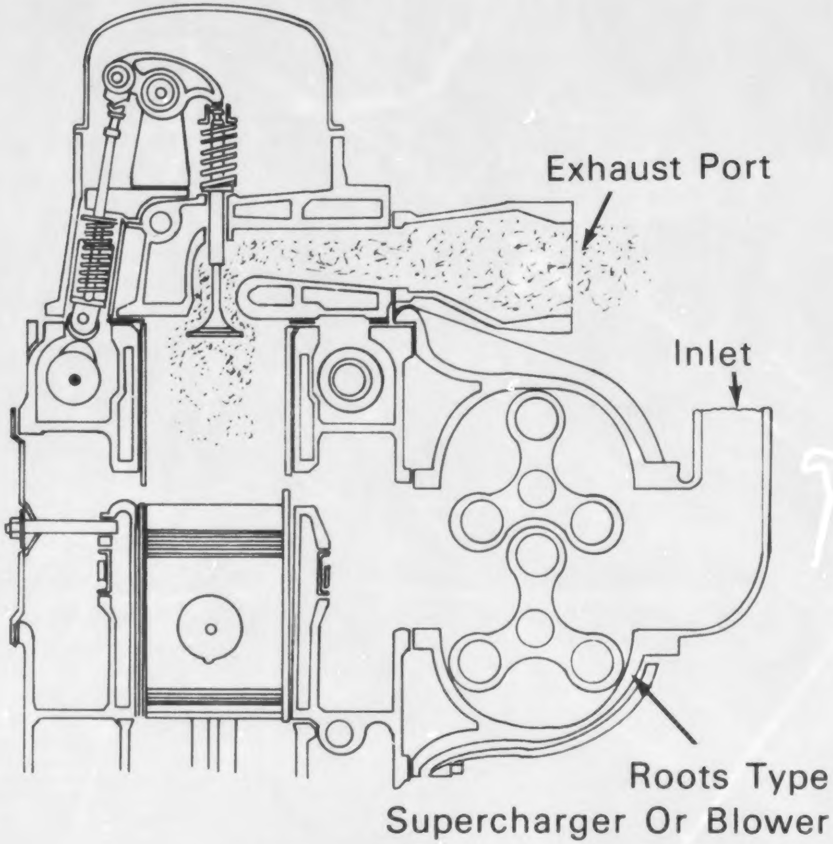
733

Scavenging Pump And Blower


Power Cylinder
Fuel-Air Vapor
Scavenging Pump
Crankshaft Drives Pump

POWER PISTON

734


Exhaust Port
Inlet
Roots Type
Supercharger Or Blower

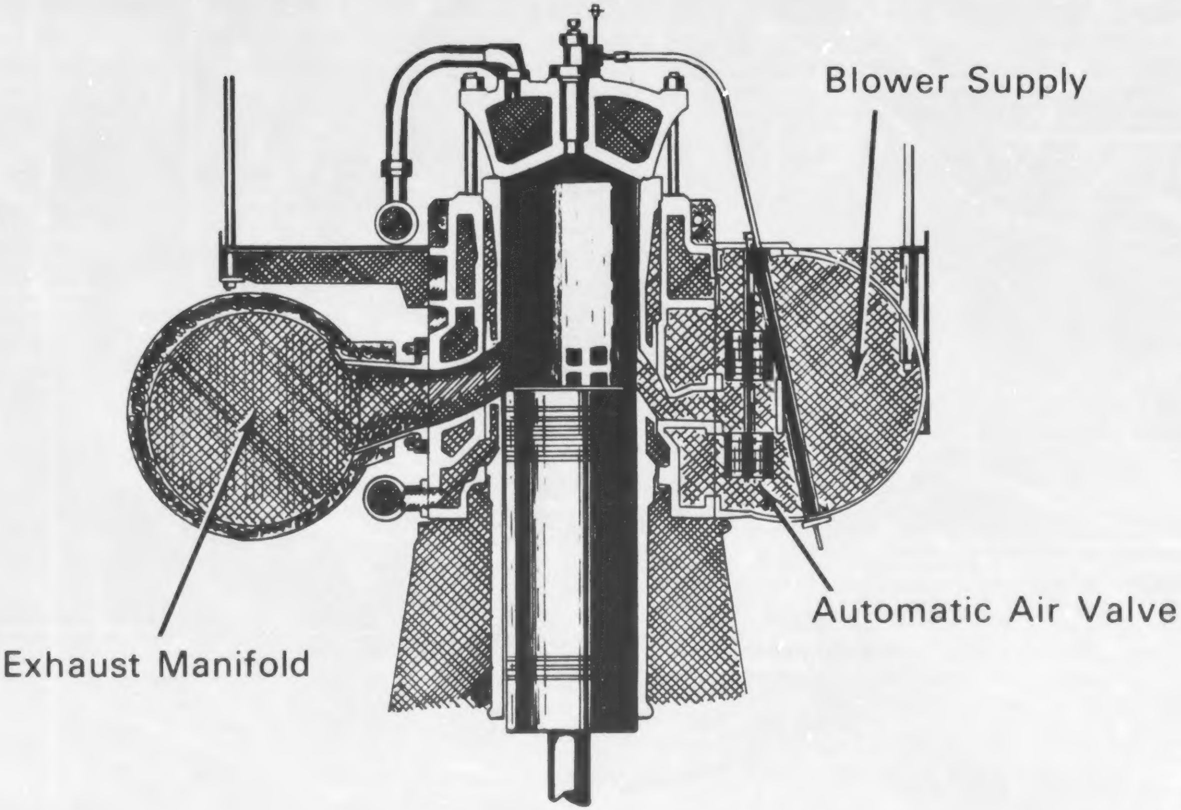
POSITIVE DISPLACEMENT

735

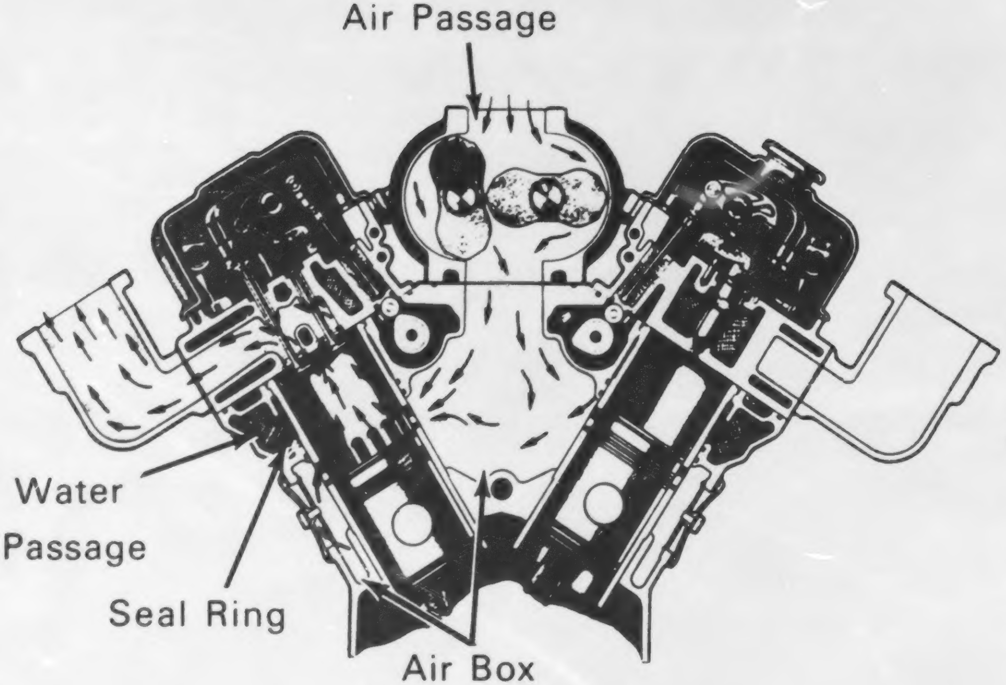
TM 5

D:F-107-D

Port-Scavenged Engine

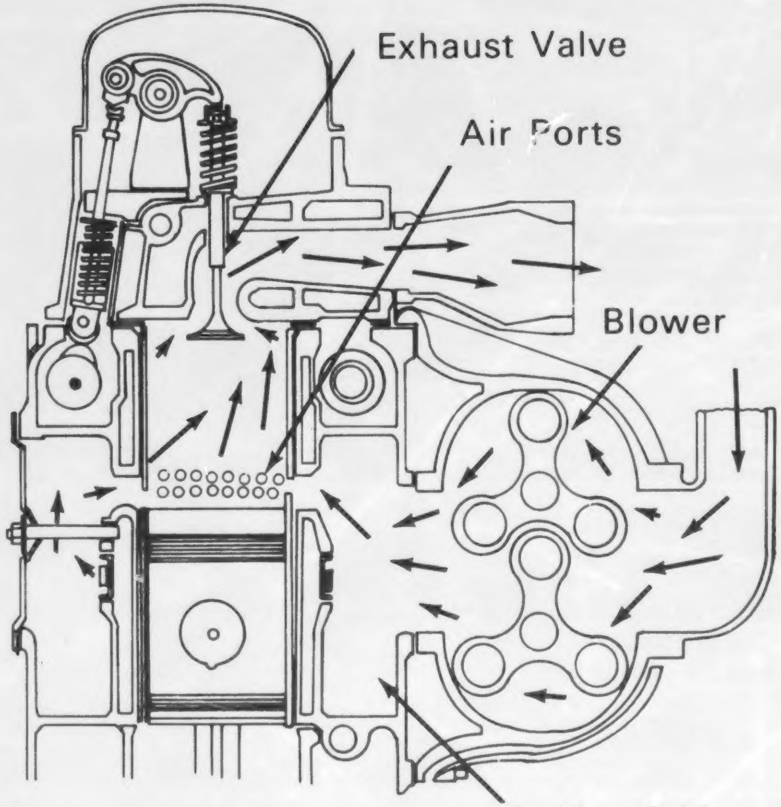

Blower Supply
Automatic Air Valve
Exhaust Manifold

Valve-Scavenged Engine


Air Passage
Water Passage
Seal Ring
Air Box

V-TYPE

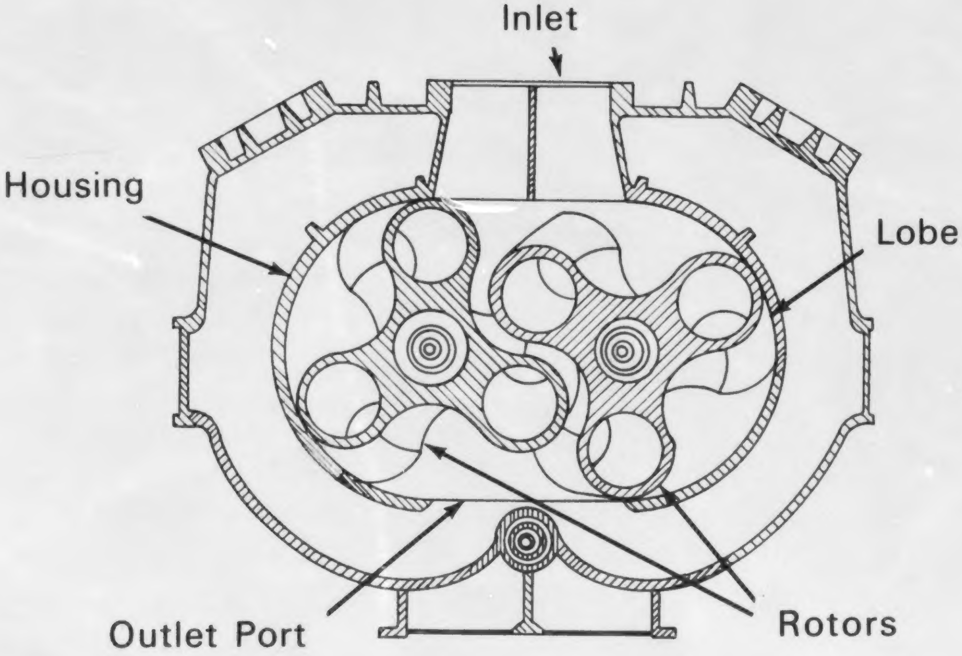
738


Exhaust Valve
Air Ports
Blower
Air Manifold

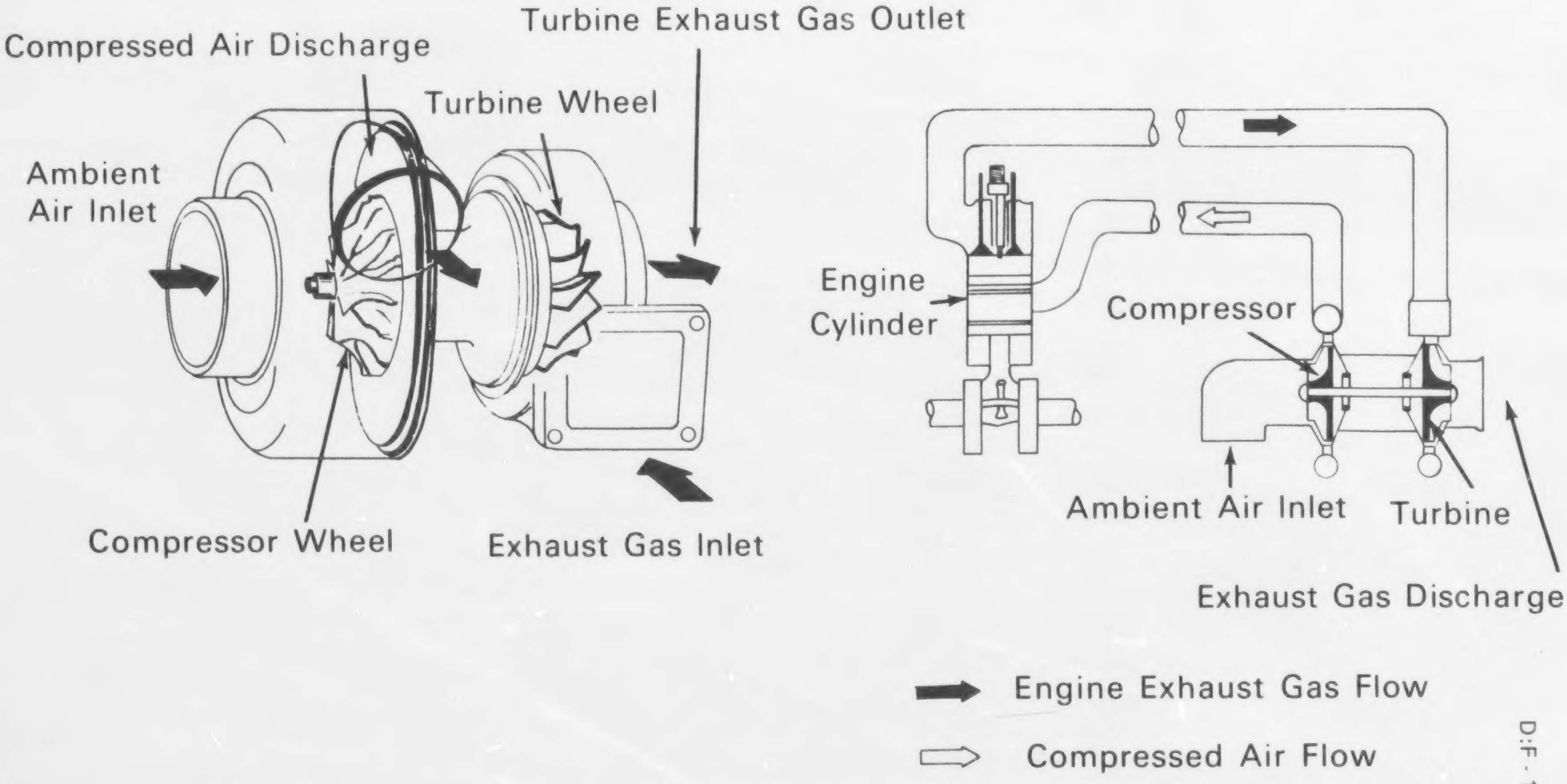
IN-LINE-TYPE

739

Positive Displacement Supercharger


Inlet
Housing
Lobe
Outlet Port
Rotors

Centrifugal-Type Supercharger


Compressed Air Discharge
Turbine Exhaust Gas Outlet
Turbine Wheel
Ambient Air Inlet
Compressor Wheel
Exhaust Gas Inlet
Engine Cylinder
Compressor
Ambient Air Inlet
Turbine
Exhaust Gas Discharge
➡ Engine Exhaust Gas Flow
⇨ Compressed Air Flow

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #1--TEST AN ENGINE FOR AIR FLOW RESTRICTION

I. Tools and materials

A. Vacuum gauge

B. Basic hand tool set

C. Live engine

D. Shop towels

E. Engine technical manual

F. Safety glasses

II. Procedure

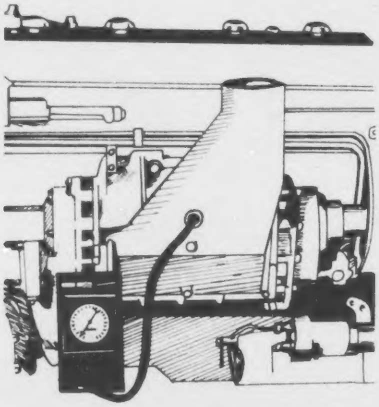
(CAUTION: Follow all shop safety procedures.)

(NOTE: When the air flow is restricted there is more vacuum or suction in the cylinders. This can cause oil to be drawn in around the valve stems and pistons and so increase oil consumption.)

A. Warm up the engine

B. Connect the vacuum gauge to the intake manifold (Figure 1)

FIGURE 1



C. Set engine speed at fast idle

D. Compare the reading on the gauge to the specifications in the engine technical manual

(NOTE: Too high a reading means that there is a restriction in the air intake system.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #2--INSPECT A TURBOCHARGER FOR SATISFACTORY OPERATION

I. Tools and materials

A. Basic hand tool set

B. Live engine with turbocharger

C. Shop towels

D. Safety glasses

E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Inspect the mounting and connections of the turbocharger to be certain they are secure and there is no leakage of oil or air

B. Check the engine crankcase to be sure there is no restriction to oil flow

C. Inspect and service air cleaner according to instructions in the operator's manual

D. Operate the engine at approximate rated output and listen for unusual turbocharger noise

(CAUTION: If a shrill whine (other than normal) is heard, stop the engine immediately. The whine means that the bearings are about to fail. Remove the turbocharger for inspection.)

(NOTE: Do not confuse the whine heard during "run down", as the engine stops, with a bearing failure during operation. Other unusual turbocharger noises could mean improper clearance between the turbine wheel and housing. If such noises are heard, remove the turbocharger for inspection. See the engine technical manual.)

E. . Check the turbocharger for unusual vibration while engine is operating at rated output

(NOTE: Unusual vibrations like noise may require that the turbocharger be removed and inspected.)

F. Check engine under load conditions

(NOTE: Excessive exhaust smoke indicates incorrect fuel-air mixture. This could be due to engine overload or turbocharger malfunction.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #3--REMOVE, DISASSEMBLE, SERVICE, ASSEMBLE, AND INSTALL A TURBOCHARGER

I. Tools and materials

A. Engine with turbocharger

B. Basic hand tool set

C. Chain hoist

D. Lifting sling

E. Torque wrench

F. Dial indicator

G. Soft hammer

H. Compressed air source

I. Noncaustic solvent

J. Silicone carbide abrasive cloth

K. Crocus abrasive cloth

L. Eye protection

M. Shop towels

N. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Remove turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing
2. Disconnect the air inlet hose attached to the compressor housing
3. Remove the oil inlet line from the top of the center housing
4. Remove the oil outlet line from the bottom of the center housing

JOB SHEET #3

5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly

6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket

7. Lift the turbocharger assembly away from the engine and place it on a bench

8. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material

9. Clean the exterior of the turbocharger with noncaustic cleaning solvent before disassembly

B. Disassemble turbocharger

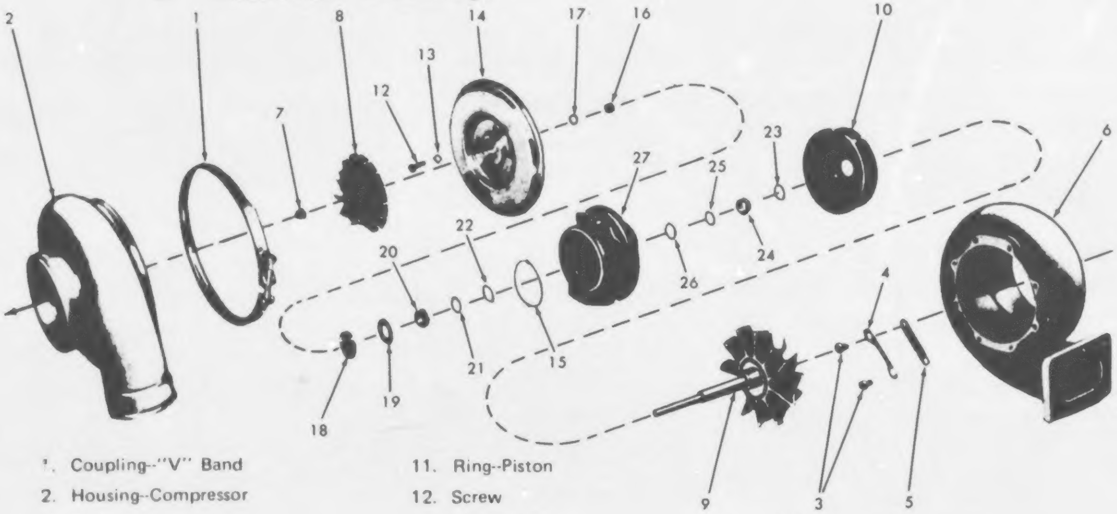


FIGURE 1

1. Coupling--"V" Band
2. Housing--Compressor
3. Bolt
4. Lockplate
5. Clamp--Turbine Housing
6. Housing--Turbine
7. Nut--Self-Locking
8. Wheel--Compressor
9. Shaft--Turbine Wheel Assembly
10. Shroud--Turbine Wheel
11. Ring--Piston
12. Screw
13. Lockplate
14. Backplate Assembly
15. Ring--Seal
16. Spacer--Thrust
17. Ring--Piston
18. Collar--Thrust
19. Washer--Inboard Thrust
20. Bearing
21. Washer--Bearing
22. Ring--Snap
23. Ring--Snap
24. Bearing
25. Washer--Bearing
26. Ring--Snap
27. Housing--Center

1. Loosen the "V" band coupling securing the compressor housing (2) to the backplate assembly (14)

2. Remove the compressor housing and "V" band (Figure 1)

3. Remove the eight bolts (3) securing the four lockplates (4) and turbine housing clamps (5) to the center housing (27) and turbine housing (6)

JOB SHEET #3

4. Remove the turbine housing from the center housing

   (CAUTION: Exercise care when removing the center housing and turbine housing to prevent damage to the compressor of the turbine wheel.)

   (NOTE: Tap the housing with a soft hammer if force is needed for removal.)

5. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture

6. Remove the wheel nut (7) from the shaft

   (CAUTION: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.)

7. Press the compressor wheel (8) from the wheel shaft assembly (9)

8. Withdraw the wheel shaft assembly (9) and the wheel shroud (10) from the center housing

9. Remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (27)

10. Remove the backplate assembly

11. Remove the seal ring (15) from the groove in the center housing

12. Remove the thrust spacers (16) and piston ring (17) from the backplate assembly

13. Remove the thrust collar (18), inboard thrust washer (19), bearing (20), bearing washer (21), and snap ring (22) from the center housing

14. Remove the snap ring (23), bearing (24), bearing washer (25), and snap ring (26) from the opposite end of the center housing

C. Clean turbocharger

(NOTE: Before cleaning, inspect the parts for signs of burning, rubbing, or other damage which might not be evident after cleaning.)

1. Soak all parts in a noncaustic cleaning solvent for about 25 minutes.

2. After soaking, use a stiff bristle brush and remove all dirt particles

JOB SHEET #3

3. Dry all [illegible] parts thoroughly

   (CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.)

   (NOTE: Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.)

4. Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air

5. Clean the oil passage in the center housing thrust plate with dry compressed air

6. Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out

   (NOTE: An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.)

D. Inspect turbocharger

1. Inspect all of the parts for signs of damage, corrosion, or deterioration

2. Check for nicked, crossed, or stripped threads

3. Visually check the turbine wheel for signs of rubbing

4. Inspect the shaft for signs of scoring, scratches, or bearing seizure

5. Check the compressor wheel for signs of rubbing or damage from foreign material

6. Check to see that the wheel bore is not galled

   (NOTE: The wheel must be free of dirt and other foreign material.)

7. Inspect the seal parts for signs of rubbing or scoring of the running faces

8. Inspect the housing for contact with the rotating parts

   (NOTE: The oil and air passages must be clean and free of obstructions.)

JOB SHEET #3

9. Using a silicone carbide abrasive cloth for aluminum parts, or a crocus abrasive cloth for steel parts, burnish or polish any minor surface damage that may appear

10. Replace the bearings and thrust washer if they show signs of nicks, scores, shellac deposits, or foreign material imbedment

    (NOTE: It is recommended that when one rotor shaft bearing needs replacement that both bearings be replaced at the same time.)

11. Inspect the exhaust outlet elbow seal ring for signs of wear or breakage

E. Assemble turbocharger

(NOTE: Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.)

1. Lubricate the bearings (20 and 24) with clean engine oil

2. Install a new snap ring (26), bearing washer (25), bearing (24), and new snap ring (23) in the turbine end of the center housing (27)

3. Install a new snap ring (22), bearing washer (21), and bearing in the compressor end of the center housing

4. Install a new piston ring (17) on the thrust spacer (16) and gently insert the spacer into the backplate assembly (14)

   (NOTE: Do not force the piston ring into place.)

5. Position the inboard thrust washer (19) against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing

6. Install the thrust collar snugly against the thrust washer

7. Lubricate the thrust collar and thrust washer with clean engine oil

8. Install a new seal ring (15) in the groove at the compressor end of the center housing

JOB SHEET #3

9. Align the oil feed holes in the center housing (27) and the backplate assembly (14) and attach the backplate to the center housing with four bolts (12) and new lockplates (13)

10. Tighten the bolts to manufacturer's specified torque and bend the lockplate tangs up against the side of the bolt heads

    (NOTE: If a new backplate with a warning plate is inadvertently installed, the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.)

11. Position the wheel shroud (10) against the center housing (27) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing

    (NOTE: Be careful not to scuff or scratch the bearings when installing the shaft.)

12. Place the turbine wheel shaft assembly, shroud, center housing, and backplate upright in a suitable holding fixture

13. Heat the compressor wheel in an oven, furnace, or hot oil bath to 325°F-375°F for no more than 10 minutes

14. Position the compressor wheel over the shaft and install the wheel retaining nut

15. Tighten the nut to manufacturer's specified torque while the compressor wheel is still hot

16. After the compressor wheel has cooled to room temperature, loosen the retaining nut and inspect the nut face and the front face of the compressor wheel to be sure they are smooth and clean

17. Apply a small amount of clean engine oil to the nut threads and the nut and wheel contact faces

18. Tighten the retaining nut to manufacturer's specified torque

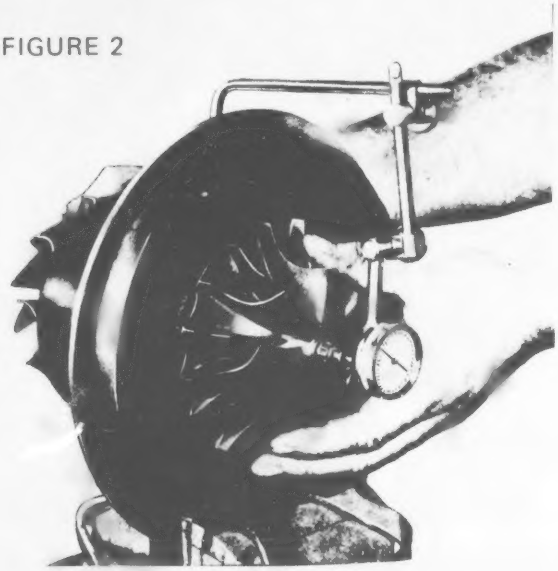
    (NOTE: Tighten the retaining nut in such a manner so as not to impose a bending load on the shaft.)

JOB SHEET #3

19. Check the bearing axial end play

    a. Clamp the center housing assembly in a bench vise equipped with soft jaws (Figure 2)

FIGURE 2



    b. Fasten a dial indicator with magnetic base to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Figure 2)

    c. Move the shaft axially back and forth by hand

    (NOTE: If the total dial indicator readings do not fall within the manufacturer's specified limits, repair or replace the rotating assembly.)

20. Position the turbine housing (6) against the center housing (27) and secure it in place with four clamps (5), four new lockplates (4), and eight bolts (3)

21. Tighten the bolts to 100-110 lb-in torque

22. Position the compressor housing (2) against the center housing (27) and secure it in place with the "V" band coupling (1)

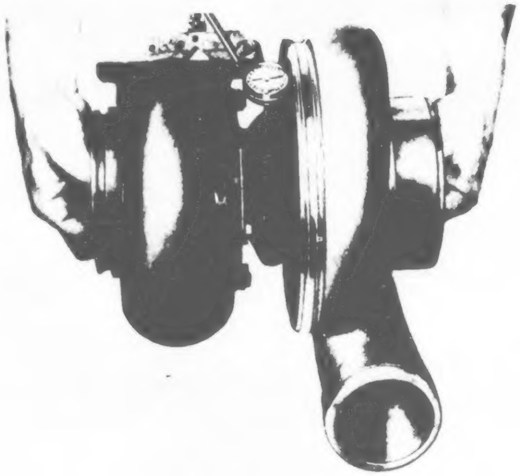
23. Tighten the nut on the "V" band coupling to manufacturer's specified torque

JOB SHEET #3

24. Check the shaft radial movement

    a. Position the magnetic base with the swivel adaptor on the flat surface of the turbine housing inlet flange (Figure 3)

FIGURE 3



    b. Fasten the dial indicator extension rod to the dial indicator and attach the dial indicator to the swivel adaptor

    c. Insert the extension rod into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft

    (NOTE: Make sure the extension rod does not make contact with the sides of the center housing; otherwise it will be impossible to obtain an accurate reading.)

    d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft (Figure 3)

    (NOTE: If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.)

JOB SHEET #3

25. Stamp the letter "R" in the lower left hand corner of the nameplate to identify that the turbocharger has been reworked

F. Install turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed

3. Place the turbocharger assembly into position on the mounting bracket

4. Secure the turbocharger to the mounting bracket with bolts, lock washers, and nuts

   (NOTE: Tighten the nuts just enough to hold the turbocharger tight against the bracket.)

5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps

6. Tighten the turbocharger to exhaust manifold adaptor bolts securely

7. Remove the chain hoist and lifting sling from the turbocharger

8. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block

9. Attach the oil inlet line to the cylinder block

10. Before starting the engine, make sure that there is adequate lubricating oil in the turbocharger

    a. Clean the area around the oil inlet opening, then pour about four ounces of engine oil in the oil inlet opening of the center housing

    b. Turn the rotating assembly by hand to coat the bearings, thrust washers and thrust collar with oil

    c. Hold the compressor wheel from turning and start the engine and run it at idle speed

JOB SHEET #3

d. As soon as oil appears at the end of the oil supply line, connect the oil inlet line to the top of the center housing

(NOTE: Compare oil pressure to manufacturer's specification.)

e. After the oil inlet line is attached, release the compressor wheel

11. Check all ducts and gaskets for leaks

12. Operate the engine at idle speed for a short period to provide adequate lubrication to the turbocharger bearings

13. Run at rated output and listen for sounds of metallic contact from the turbocharger

(NOTE: If any such noise is apparent, shut down the engine immediately and correct the cause. After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #4--DISASSEMBLE A ROOTS-TYPE BLOWER

I. Tools and materials

A. Basic hand tools

B. Plastic hammer

C. Shop towels

D. Safety glasses

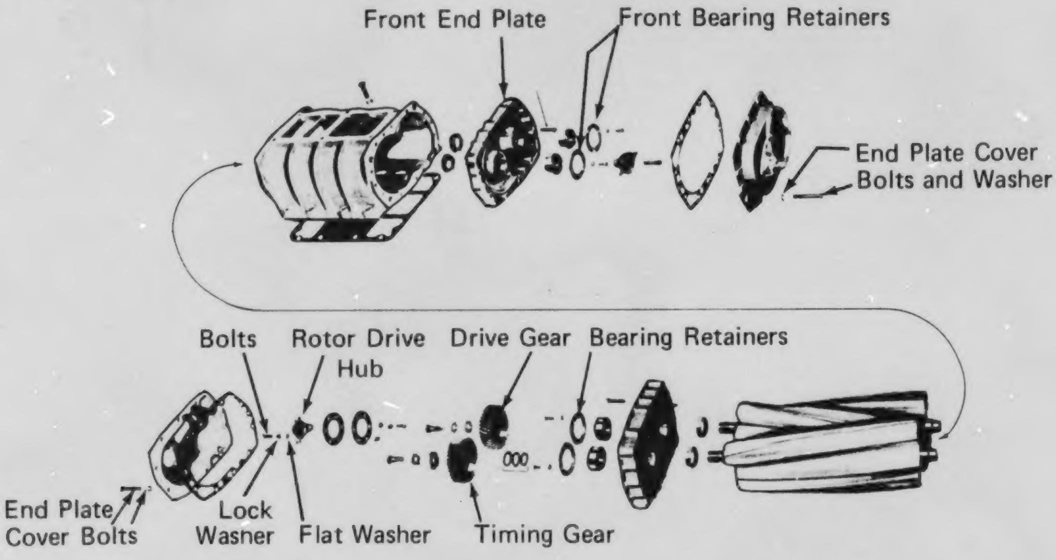
E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Remove the ten bolts and lock washers securing the end plate covers to the blower front and rear end plates (Figure 1)

FIGURE 1


Front End Plate
Front Bearing Retainers
End Plate Cover Bolts and Washer
Bolts
Rotor Drive Hub
Drive Gear
Bearing Retainers
End Plate Cover Bolts
Lock Washer
Flat Washer
Timing Gear

© General Motors Corporation

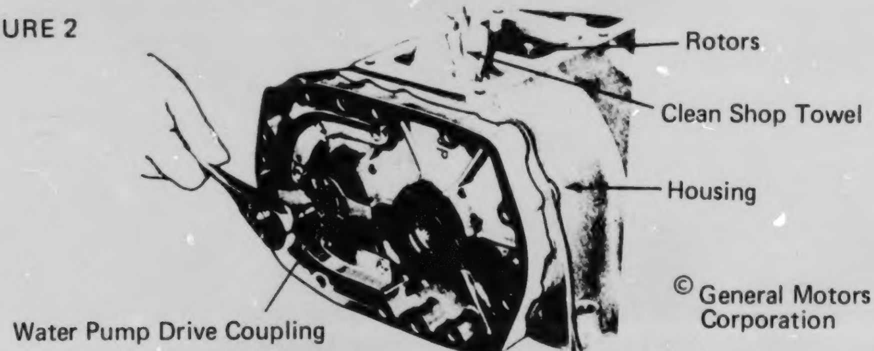
JOB SHEET #4

B. Tap ends of the end plate covers with a plastic hammer to loosen the covers from the gaskets and dowel pins in the end plates

C. Remove the covers and gaskets from the end plates

D. Place a clean, folded shop towel between the rotor and the housing to prevent the rotors from turning (Figure 2)

FIGURE 2



© General Motors Corporation

Removing Water Pump Drive Coupling
Bolt from Blower Rotor Shaft

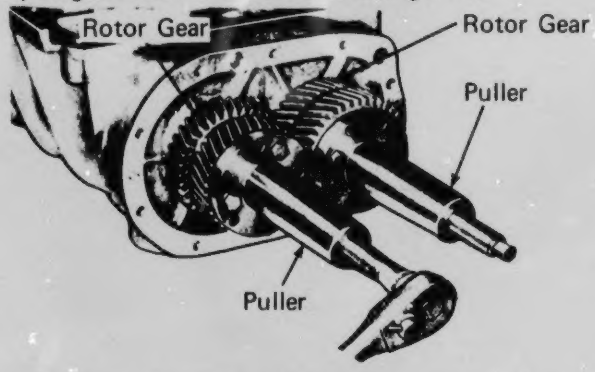
E. Remove the bolt securing the water pump drive coupling to the blower shaft (Figure 2)

F. Remove the bolts, lock washers, and plain washers securing the blower rotor drive hub and drive hub plates to the blower rotor timing gear (Figure 1)

G. Remove the bearing retainers from the gear (Figure 1)

H. Secure the pullers to the gears with bolts, and turn the puller screws evenly clockwise and pull gears from the rotor shafts (Figure 3)

FIGURE 3



Removing Blower Rotor Gears from Blower Rotor Shafts

© General Motors Corporation

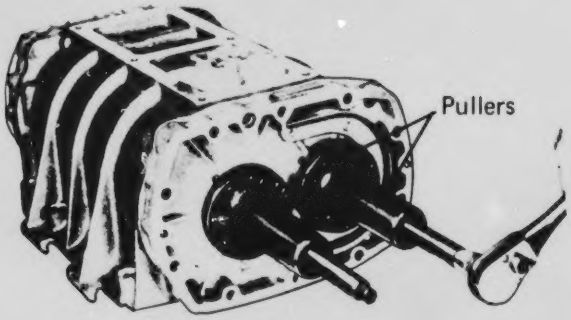
(NOTE: Both gears must be pulled from the rotor at the same time.)

JOB SHEET #4

I. Remove the bolts and lock washers securing the rotor shaft bearing retainers from the front end plate, and remove the retainers (Figure 1)

J. Remove the blower rear end plate and bearing assembly from the blower housing and rotors with the two pullers (Figure 4)

FIGURE 4



Removing Rear End Blower Plate

© General Motors Corporation

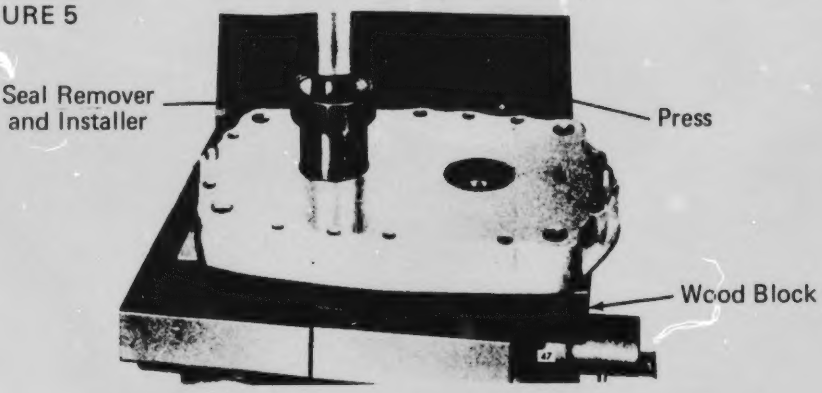
1. Remove the two fillister head screws securing the rear end plate to the blower housing, and loosen the two fillister head screws securing the front end plate to the housing approximately three turns
2. Back out the center screws of the pullers far enough to permit the flange of each puller to lay flat on the face of the end plate
3. Secure the pullers to the end plate with six bolts

   (NOTE: Be sure bolts are threaded all the way into the tapped holes to eliminate possible damage to the end plate.)
4. Turn the two puller screws evenly clockwise and withdraw the end plate and bearing from the blower housing and rotors
5. Remove the other end plate in the same manner

JOB SHEET #4

K. Remove the bearings and lip type oil seals from the blower end plate (Figure 5)

FIGURE 5



Removing Oil Seal Ring Carrier (or Seal Ring Collar) and Bearing from End Plate

© General Motors Corporation

(NOTE: When performing a major overhaul, discard the oil seals; otherwise inspect the oil seals.)

1. Support the outer face of the end plate on wood blocks on the bed of an arbor press
2. Place the long end of the oil seal remover and installer down through the oil seal and into the bearing

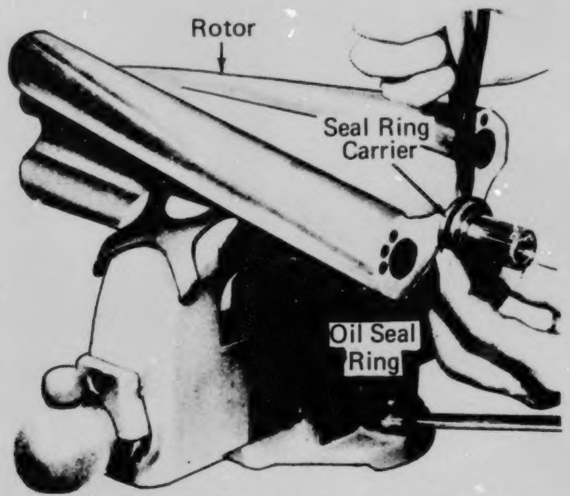
   (NOTE: Remove the seals from the end plates at the same time the individual bearings are removed.)

3. With the opposite end of the remover under the ram of the press, press the bearing and oil seal out of the end plate (Figure 5)
4. Remove the remaining bearings and oil seals from the end plates in the same manner

JOB SHEET #4

L. Remove the bearings and ring tye oil seals, carriers, and collars from the blower rotor shafts (Figure 6)

FIGURE 6

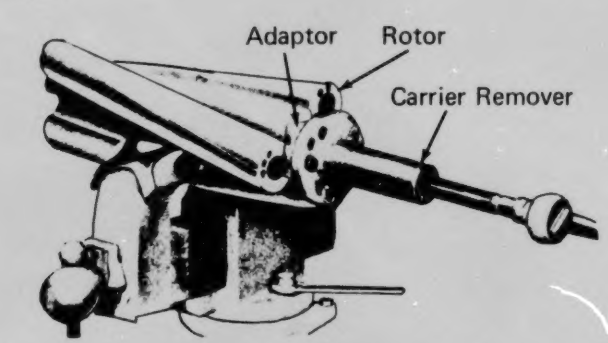


Removing Oil Seal Ring From Carrier

© General Motors Corporation

1. Clamp one lobe of the rotor in a bench vise equipped with soft jaws; tighten the vise just enough to hold the rotor stationary (Figure 6)
2. Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers (Figure 6)
3. Place the seal ring carrier remover over the carrier; make sure the adapter is seated in the groove of the carrier (Figure 7)

FIGURE 7



Removing Oil Seal Ring Carrier from Blower Rotor Shaft

© General Motors Corporation

JOB SHEET #4

4. Back out the center screw of puller far enough to permit the puller flange to lay flat against the adaptor

5. Place the puller over the end of the rotor shaft and against the adaptor on the oil seal ring carrier, and secure the puller to the adaptor with two bolts

6. Turn the puller screw clockwise and pull the oil seal ring carrier from the rotor shaft (Figure 7)

7. Remove the remaining oil seal ring carriers from the rotor shafts in the same manner

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #5--INSPECT A ROOTS-TYPE BLOWER

I. Tools and materials

A. Basic hand tools

B. Shop towels

C. Clean fuel oil

D. Safety glasses

E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Wash all of the blower parts in clean fuel oil and dry them with compressed air

B. Examine the bearings for any indications of corrosion or pitting

C. Lubricate each bearing with light engine oil

D. Hold the bearing inner race to keep it from turning and revolve the outer race slowly by hand to check for rough spots

E. Check the double-row ball bearings for any sign of end play

(NOTE: The ball bearings are preloaded and should **not** have any end play.)

F. Check the oil seal rings, carriers, and collars for wear and scoring

(NOTE: If worn excessively, they must be replaced.)

G. Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring

(NOTE: If the rotors are slightly scored or burred, clean with emery cloth.)

H. Inspect the bearing and oil seal contact surfaces of the shaft for wear and scoring

I. Inspect the inside surface of the blower housing for burrs and scoring

JOB SHEET #5

J. Check the finished ends of the blower housing for flatness and burrs; the end plates must set flat against the blower housing

(NOTE: If the finished face is slightly scored or burred, clean with emery cloth.)

K. Examine the serrations in the blower timing gears for wear and peening; check the teeth for wear, chipping, or damage

L. Check the blower drive shaft serrations for wear or peening; replace the shaft if it is bent

M. Inspect the blower drive coupling springs (pack) and the cam for wear

(NOTE: Replace all worn or excessively damaged blower parts.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #6--ASSEMBLE A ROOTS-TYPE BLOWER

I. Tools and materials

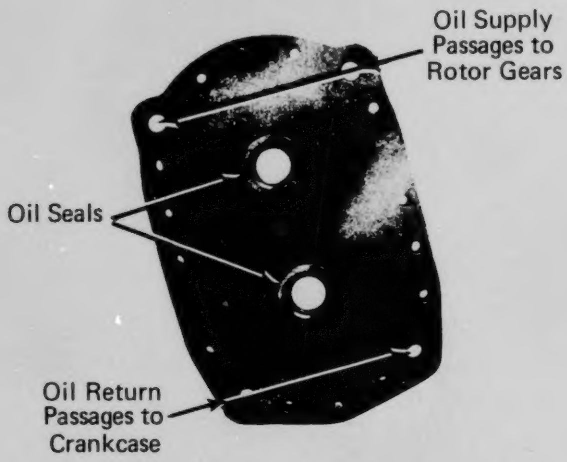
- A. Basic hand tools
- B. Plastic hammer
- C. Shop towels
- D. Safety glasses
- E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Install the lip type oil seals (Figure 1)

FIGURE 1


Oil Supply Passages to Rotor Gears
Oil Seals
Oil Return Passages to Crankcase

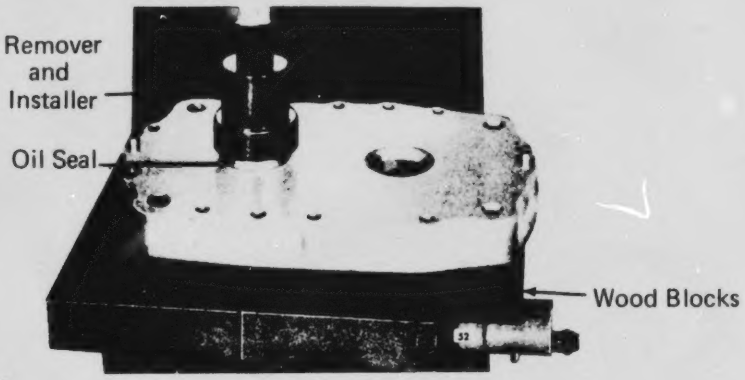
Blower End Plate and Lip Type Oil Seal Location

© General Motors Corporation

1. Support the blower end plate, finished surface facing up, on wood blocks on the bed of an arbor press (Figure 2)

JOB SHEET #6

FIGURE 2



Installing Oil Seal (or Seal Ring Collar)
in Blower End Plate

© General Motors Corporation

2. Start the oil seal straight into the bore in the end plate with the sealing edge facing down (toward the bearing bore)

3. Place the short end of oil seal remover and installer in the oil seal and under the ram of the press (Figure 2)

4. Press the oil seal into the end plate until the shoulder on the installer contacts the end plate

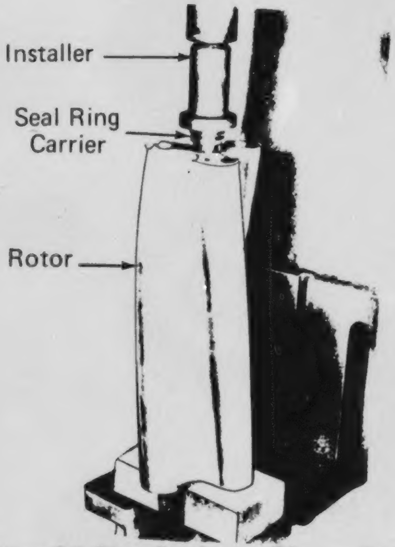
5. Install the remaining oil seals in the end plates in the same manner

B. Install the ring type oil seal, carriers, and collars on the rotor shafts and in the end plates

JOB SHEET #6

1. Support one of the rotor assemblies on wood blocks on the bed of an arbor press as shown (Figure 3)

FIGURE 3



© General Motors Corporation

Installing Oil Ring Carrier on Blower Rotor Shaft

2. Lubricate the inside diameter of the oil seal ring carrier with engine oil, then start the carrier straight over the end of the rotor shaft with the chamfered inside diameter and facing the rotor

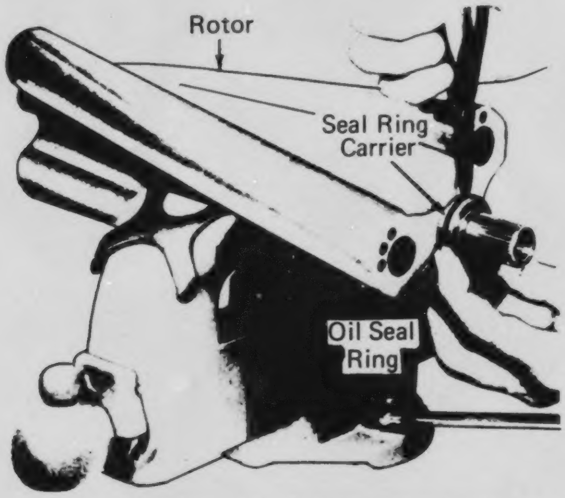
3. Place the oil seal ring carrier installer over the end of the rotor shaft and against the carrier with the end of the installer under the ram of the press; then, press the carrier down tight against the rotor (Figure 3)

4. Install the remaining oil seal ring carriers on the rotor shafts in the same manner

JOB SHEET #6

5. Install an oil seal ring in the ring groove of each carrier with a pair of snap ring pliers (Figure 4)

FIGURE 4



Installing Oil Seal Ring From Carrier

© General Motors Corporation

(CAUTION: To avoid breaking the oil seal rings, do not spread them any more than necessary to place them over the end of the carrier.)

6. Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press (Figure 2)
7. Lubricate the outside diameter of a seal ring collar with engine oil; then, start the chamfered outside diameter end of the collar straight into the bore in the end plate
8. Place the oil seal ring collar installer on top of the seal ring collar and under the ram of the press in the same manner as shown (Figure 2)
9. Press the collar into the end plate until the shoulder on the installer contacts the end plate (Figure 2)
10. Install the remaining oil seal ring collars in the end plates in the same manner

C. Assemble rotors and end plate

(NOTE: No gaskets are used between the end plates and the housing; therefore, the mating surfaces must be perfectly flat and smooth.)

JOB SHEET #6

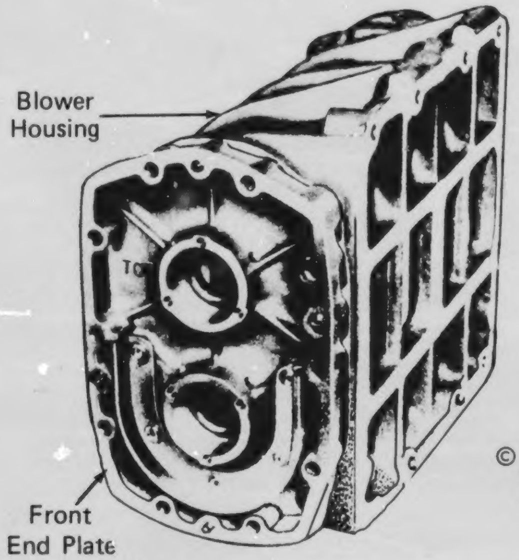
1. For naturally aspirated engines, apply a rubber base sealant as required to avoid leakage between the end plates and the blower housing

2. For turbocharged engines, apply a rubber base sealant between the entire joint face of both ends of blower housing to end plates interfaces, especially around the bolt holes and dowels

   (NOTE: Be sure no sealant protrudes into the blower housing; the sealant must not prevent the end plates from laying against the housing.)

3. Install the blower front end plate, making sure the mark "TOP" on the outer ribbed side is at the top of the blower housing, identified by the flange which supports the housing on the top edge of the cylinder block (Figure 5)

FIGURE 5



© General Motors Corporation

Position of Blower Front End Plate on Housing

4. Check the dowel pins; the dowel pins must project .300" from the flat inner face, and .270" from the outer face of the front end plate to assure proper alignment of the end plate to the housing and the cover to the end plate

5. Place the blower housing on a bench with the top of the housing up, and the front end of the housing facing the outside of the bench

6. Position the end plate in front of the blower housing with the flat finished face of the end plate facing the housing and the end marked "TOP" facing the flanged side of the housing

JOB SHEET #6

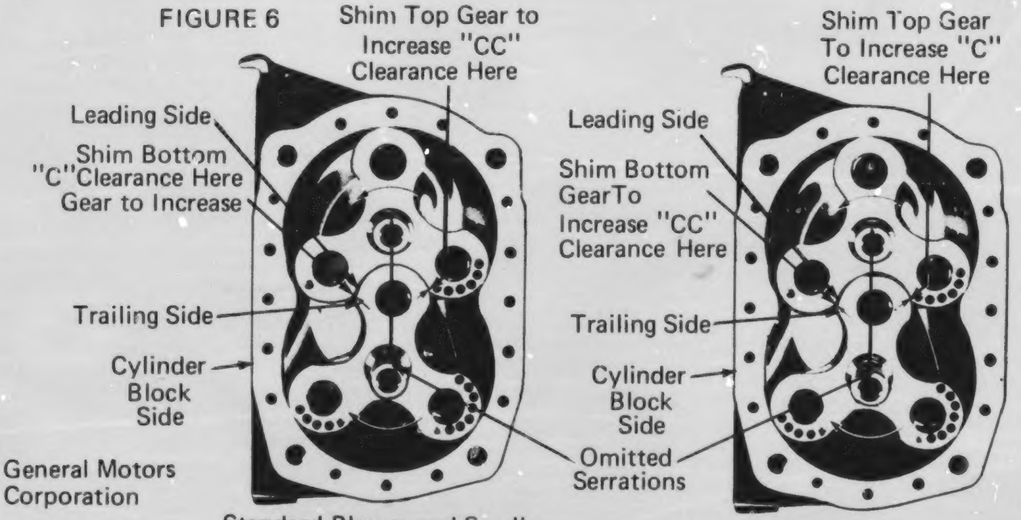
7. Start the dowel pins straight into the dowel pin holes in the housing; push or tap the end plate against the housing

8. Insert the two fillister head screws through the end plate and thread them into the housing; then, tighten the screws to 5-10 lb.-ft. torque

   (NOTE: Do not use lock washers on these screws.)

9. Make sure the rotor is assembled in the blower housing with the omitted serrations in the rotor shaft aligned as shown (Figure 6)

FIGURE 6


Shim Top Gear to Increase "CC" Clearance Here
Leading Side
Shim Bottom "C"Clearance Here Gear to Increase
Trailing Side
Cylinder Block Side
Shim Top Gear To Increase "C" Clearance Here
Leading Side
Shim Bottom GearTo Increase "CC" Clearance Here
Trailing Side
Cylinder Block Side
Omitted Serrations

© General Motors Corporation

Standard Blower and Smaller Diameter Rotor Blowers

Former Reduction Blowers

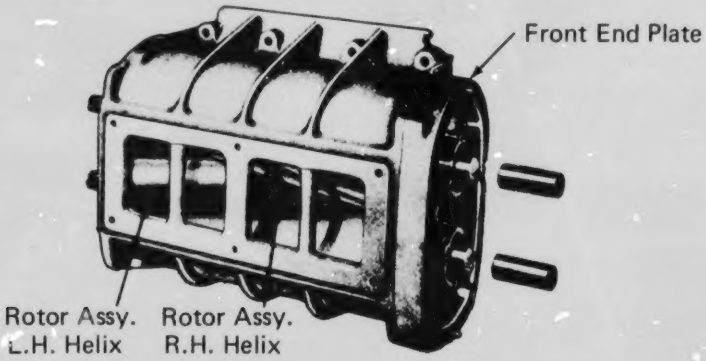
(Views From Gear End)

10. Place an oil seal pilot on the short (non-splined) end of each rotor shaft; then, place the rotors in mesh with the omitted serrations in the shafts in alignment (Figure 6)

JOB SHEET #6

11. Insert the blower rotors with oil seal pilots straight into the blower housing with the right-hand helix rotor at the top, flange side of the housing; then, push the rotor shaft and oil seal pilots on through the oil seal in the front end plate as shown (Figure 7)

FIGURE 7



Assembling Blower Rotors into Housing and Front End Plate

© General Motors Corporation

12. Remove the oil seal pilots from the rotor shafts

13. Attach the blower rear end plate to the blower housing

14. Reverse the blower housing on the bench (rear end of housing facing the outside of the bench)

15. Place an oil seal pilot on the serrated end of each rotor shaft

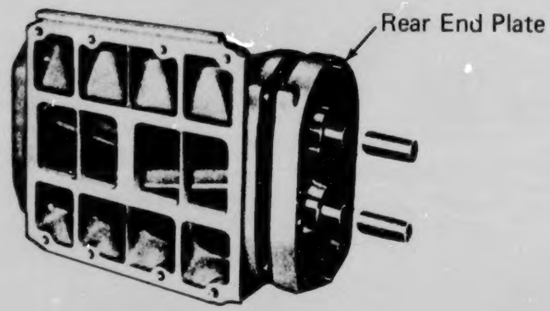
16. Check dowel pin height

17. Place the rear end plate in position in front of the oil seal pilots with the flat finished face of the end plate facing the blower housing and the mark "TOP" on the end plate at the top flange side of the housing

JOB SHEET #6

18. Place the rear end plate over the oil seal pilots and start the dowel pins straight into the dowel pin holes in the housing; then, push or tap the end plate against the housing (Figure 8)

FIGURE 8



Installing Blower Rear End Plate

© General Motors Corporation

19. Insert the two fillister head screws through the end plate and thread them into the housing; then, tighten the screws to 5-10 lb.-ft. torque

    (NOTE: Do not use lockwashers on these screws.)

20. Remove the oil seal pilots from the rotor shafts

D. Install blower rotor shaft bearings and gears

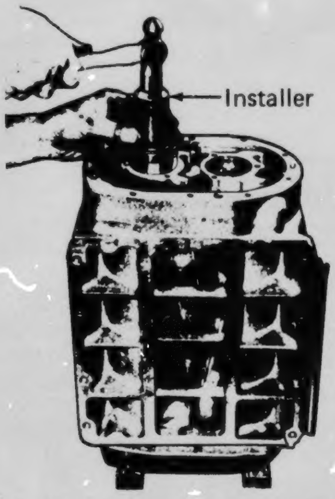
   1. With the blower housing, rotors and end plates supported in a vertical position on the two wood blocks, install the roller bearings on the rotor shafts and in the front end plate as follows

      a. Lubricate one of the roller bearings with engine oil; then, start the bearing, numbered end up, straight on one of the rotor shafts

JOB SHEET #6

b. Place installer on top of the bearing and tap the bearing on the shaft and into the front end plate as shown (Figure 9)

FIGURE 9



© General Motors Corporation

Installing Roller Bearing on Rotor Shaft and in Front End Plate

c. Install the second roller bearing on the remaining rotor shaft in the same manner

d. Place the bearing retainers on top of the bearings and the end plate; then, install the retainer bolts and lock washers, and tighten the bolts to 7-9 lb.-ft. (9-12 Nm) torque

2. Start the end of the water pump drive coupling straight into the left-hand helix rotor shaft; then, place a clean shop towel between the blower rotors to prevent them from turning

3. Install the drive coupling retaining bolt and draw the coupling and slinger tight against the end of the shaft; then, tighten the bolt to 18 lb.-ft. (24 NM) torque

4. Affix a new gasket to the blower front end plate cover

5. Position the end plate cover over the end plate dowel pins, with the large hole in the cover toward the top of the end plate; then, push the cover against the end plate

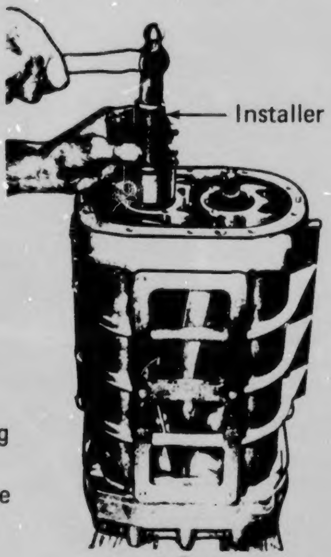
6. Install the ten bolts and lock washers and tighten the bolts to 13-17 lb.-ft. torque

7. Install the ball bearings on the rotor shafts and in the rear end plate as follows

JOB SHEET #6

a. Reverse the position of the blower housing on the two wood blocks (Figure 10)

FIGURE 10



Installing Ball Bearing
on Rotor Shaft
and in Rear End Plate

© General Motors Corporation

b. On a blower with ring type oil seals, insert the two fillister head screws through the rear end plate and thread them into the housing; then, tighten the screws to 5-10 lb.-ft. torque

(NOTE: Do not use lock washers on these screws.)

c. Lubricate one of the ball bearings with engine oil; then, start the bearing numbered end up, straight on one of the rotor shafts

d. Place installer on top of the bearing and tap the bearing straight on the shaft and into the rear end plate as shown (Figure 10)

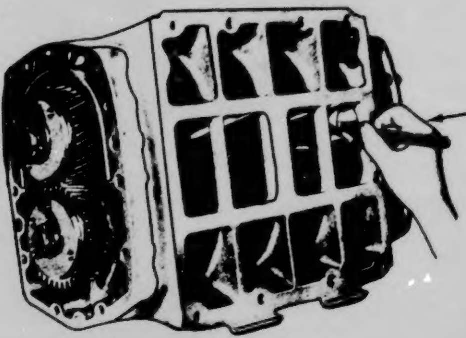
e. Install the second ball bearing on the remaining rotor shaft in the same manner

f. Place the bearing retainers on top of the bearing and the end plate; then, install the retainer bolts and lock washers and tighten the bolts to 7-9 lb.-ft. torque

JOB SHEET #6

8. Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gauge as shown (Figure 11)

FIGURE 11



© General Motors Corporation

Measuring End Clearance Between Blower Rotors and End Plate

9. Install the blower rotor timing gears on a standard blower or a smaller diameter rotor blower as follows

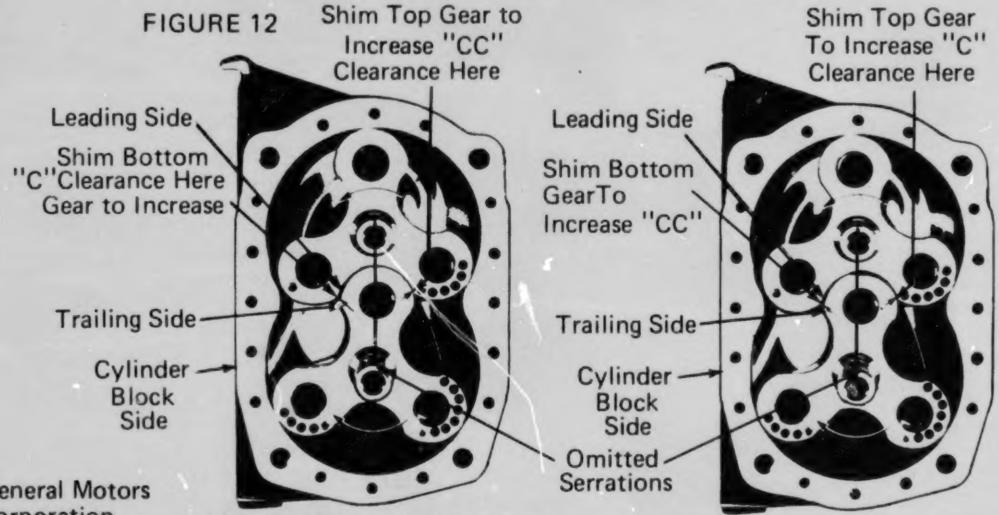
   (NOTE: One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serration in alignment.)

   a. Place the blower housing and rotor assembly on the bench with the air inlet side of the housing facing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench

JOB SHEET #6

b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing the top of the blower housing (Figure 12)

FIGURE 12


Shim Top Gear to Increase "CC" Clearance Here
Leading Side
Shim Bottom "C" Clearance Here Gear to Increase
Trailing Side
Cylinder Block Side
Shim Top Gear To Increase "C" Clearance Here
Leading Side
Shim Bottom Gear To Increase "CC"
Trailing Side
Cylinder Block Side
Omitted Serrations

© General Motors Corporation

Standard Blower and Smaller Diameter Rotor Blowers

Former Reduction Blowers

(Views From Gear End)

c. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly

(NOTE: When rebuilding a blower with new rotors or new gears, first install the gears on the rotor shafts without the shims; then, check the clearances between the rotors to determine the location and thickness of shims to be used (Figure 12)

d. Lubricate the serrations of the rotor shafts with engine oil

e. Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts

(NOTE: A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.)

f. Start both rotor gears straight on the rotor shafts with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor, and the omitted serrations in the gears in line with the omitted serrations on the rotor shafts

g. Thread an installer screw in the end of each rotor shaft until it bottoms

JOB SHEET #6

h. Place gear installer over the installer screw and against the right-hand helix gear, and gear installer over the installer screw and against the left-handed helix gear; then, thread a nut on each installer screw (Figure 13)

i. Place a clean shop towel between the rotors, and another one between the rotor and the housing to prevent the rotors from turning; then, turn the nuts on the installer screws clockwise as shown in Figure 13 and force the gears into position tight against the shims and bearing inner races

(NOTE: Both gears must be pressed on the rotor shafts at the same time.)

j. Remove the rotor timing gear installers from the rotor shafts

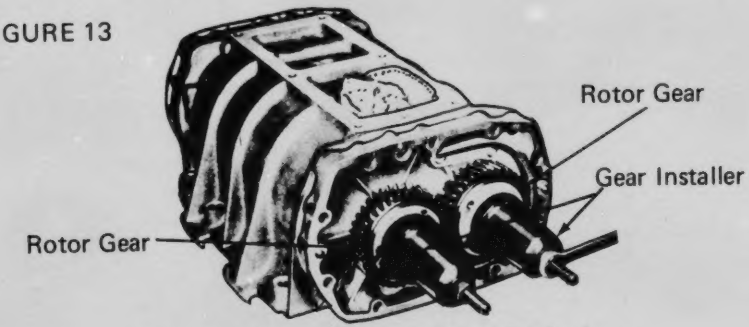
k. Place a lock washer and the gear retaining washer on one of the gear retaining bolts; then, thread the bolt into the right-hand helix rotor shaft, and guide the lugs on the retaining washer in the slots in the gear hub; then bend one of the tangs on the lock washer over into the slot of the retaining washer and tighten the gear retaining bolt to 55-65 lb.-ft. torque

l. Place a lock washer and the fuel pump drive coupling disc on the remaining gear retaining bolt; then, thread the bolt into the left-hand helix rotor shaft and guide the lugs on the disc in the slots in the gear hub; then bend one of the tangs on the lock washer over into the slot in the disc and tighten the gear retaining bolt to 55-65 lb.-ft. torque

m. Bend one of the tangs of each lock washer over against the head of the gear retaining bolt

n. Remove the cloth from the blower rotors

FIGURE 13



Installing Rotor Gears on Rotor Shafts for Preliminary Check of Clearances

© General Motors Corporation

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____ a. Unit containing an element of varying degrees of fineness to trap foreign particles

_____ b. Method of pushing air out of the cylinders during the exhaust stroke on two-cycle engines

_____ c. Opening in a cylinder block or liner for intake and/or exhaust air on two-cycle engines

_____ d. Device for sealing the intake and/or exhaust ports in a cylinder head

_____ e. Method of increasing air pressure and velocity

_____ f. Positive displacement blower to raise intake air above atmospheric pressure

_____ g. Exhaust-driven turbine which drives a centrifugal compressor

_____ h. Pipe or casting with multiple openings to connect multiple cylinders to one outlet or inlet

_____ i. Method of charging cylinders with fresh air above atmospheric pressure on the intake stroke

_____ j. Engine which is not supercharged

_____ k. Device to collect some dirt from air before it enters the main air cleaner

_____ l. Intake manifold cooled by circulated water

_____ m. A device used on turbocharged engines to cool air which has undergone compression

1. Scavenging
2. Filter
3. Blower
4. Supercharging
5. Turbocharger
6. Naturally aspirated
7. Port
8. Valve
9. Roots-type blower
10. Manifold
11. Precleaner
12. Inter cooler
13. After cooler

2. Name four parts of an air intake system.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

3. Name four parts of an exhaust system.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

4. Match types of air cleaners on the right with their processes.

   _____a. Cleaning is done by replacing element

   _____b. Cleans air by passing it through a maze of metal wool, wire, or screens saturated with oil

   _____c. Cleans air by directing it through a center tube into the inner oil cup where direction of air flow is reversed causing most of the dirt to become trapped by the oil and settle in the sump

   1. Viscous-impingement type
   2. Dry element type
   3. Wet type

5. Complete the following list of statements concerning methods of scavenging the cylinders on a two-stroke cycle engine.

   a. Crankcase

      1. ____________________

      2. Each downward movement of the piston compresses the vapor within the crankcase until the intake port or valve opens

      3. The compressed vapor escapes into the cylinder at a pressure nearly equal to atmospheric pressure

   b. Power piston

      1. Uses a separate piston and cylinder driven by the engine crankshaft

      2. ____________________

   c. Blower

      1. Uses a positive-displacement rotary blower driven by the engine

      2. ____________________

6. Distinguish between port scavenging and valve scavenging in two-cycle engines by placing an "X" next to the description of port scavenging.

   _____a. Air enters through ports in the cylinder block and gases leave through valves in the cylinder head

   _____b. Air enters and gas leaves through ports in the cylinder block or liner which the piston uncovers

7. Distinguish between positive displacement and centrifugal superchargers by placing an "X" next to the characterisitics of centrifugal superchargers.

   _____a. Driven by engine, engine exhaust, or separate motor

   _____b. Driven by chair, belt, or gear

   _____c. Resembles oil pumps in design

   _____d. Impeller normally moves thirty times engine speed

8. List four advantages of a turbocharged engine.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

9. Demonstrate the ability to:

   a. Test an engine for air flow restriction.

   b. Inspect a turbocharger for satisfactory operation.

   c. Remove, disassemble, service, assemble, and install a turbocharger.

   d. Disassemble a roots-type blower.

   e. Inspect a roots-type blower.

   f. Assemble a roots-type blower.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

ANSWERS TO TEST

1. a. 2
   b. 1
   c. 7
   d. 8
   e. 3
   f. 9
   g. 5
   h. 10
   i. 4
   j. 6
   k. 11
   l. 12
   m. 13

2. Any four of the following:

   a. Precleaner, air cleaner
   b. Supercharger (if used)
   c. Intake manifold
   d. Piping
   e. Intake valves or ports

3. Any four of the following:

   a. Ports and/or valves
   b. Exhaust manifold
   c. Piping
   d. Muffler
   e. Turbocharger (if used)

4. a. 2
   b. 1
   c. 3

5. a. Air enters the engine through the crankcase
   b. Pushes the vapor into the cylinders as the intake valve or port opens
   c. Compresses the vapor into an air chamber surrounding the intake ports

6. b

7. a, d

8. Any four of the following:

   a. Increases horsepower output of a given displacement engine
   b. Reduces weight by delivering more horsepower per pound than nonturbocharged engines
   c. Cost of a turbocharged engine is less on a dollar per horsepower basis
   d. Maintains horsepower at higher altitudes
   e. Reduces exhaust smoke by supplying excess air to reduce exhaust density

9. Performance skills evaluated to the satisfaction of the instructor

STARTING SYSTEMS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the various methods used to start diesel engines and be able to identify the components necessary to operate a starting system. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with starting systems with the correct definitions.
2. Name four major types of starting systems.
3. Complete a list of three sources of electricity that may be used in electric motor starting.
4. List two sources of compressed air for compressed starting motors.
5. Select true statements concerning how an engine is started by compressed air admission.
6. Name components of an air admission starting system.
7. Distinguish between air admission and air motor starting systems.
8. Identify the components of a hydraulic starting system.
9. Name four components of a gasoline starting system.
10. Name three components of an electric starting system.
11. Complete a list of low temperature starting aids.

STARTING SYSTEMS
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Locate an engine which uses compressed air for starting and demonstrate the starting procedures.

VII. Take field trip to different shops that use other than electric starting systems.

VIII. Demonstrate safety procedures.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  - A. Objective sheet
  - B. Information sheet
  - C. Transparency masters
    1. TM 1--Components of Air Admission Starting System
    2. TM 2--Air Starting Systems
    3. TM 3--Compressed Air Starting Motors
    4. TM 4--Components of Hydraulic Starting System
    5. TM 5--Starting Aids
    6. TM 6--Starting Aids (Continued)
  - D. Test
  - E. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair*. South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. Chicago: American Technical Society, 1974.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc. 1982.

STARTING SYSTEMS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

  A. Accumulator--A device used to store hydraulic energy under pressure for use in hydraulic cranking motor

  B. Pinion--Gear with a small number of teeth designed to mesh with a larger gear

  C. Inertia--Tendency of mass in motion to remain in motion, or if at rest, to remain at rest

  D. Compound--Dual, two systems

  E. Plenum--Enclosed space

II. Types of starting systems

  A. Hydraulic cranking motors

  B. Electric motors

  C. Gasoline engines

  D. Compressed air cranking systems

III. Sources of electricity for electric motor starting

  A. Twelve, twenty-four, or thirty-two volt storage batteries driving an electric starting motor

  B. Sixty-four or one hundred ten volt storage batteries driving the main generator as a starting motor

  (NOTE: Diesel-electric locomotives use this system.)

  C. Main switchboard in a stationary power plant where the switchboard is always energized

IV. Sources of compressed air for compressed air starting motors

  A. Separate engine and compressor

  B. Air brake compressor on highway diesel tractors

  (NOTE: The air starting motor produces more torque to turn an engine over than an electric starter motor.)

INFORMATION SHEET

V. Starting an engine by compressed air admission

  A. Air is compressed in storage tanks.

  B. Compressed air is admitted through an automatic starting valve in engine cylinder head when the piston is at top center at start of the power stroke

  C. Starting valve opening is timed by cams on the camshaft

  (NOTE: Usual starting air pressures range from 250 to 350 pounds per square inch.)

VI. Components of air admission starting system (Transparency 1)

  A. Pressure relief valve

  B. Pressure gauges

  C. Air tanks

  D. Blow-off valves

  E. Drain valves

  F. Shut-off valves

  G. Engine driven air compressor

  H. Motor driven air compressor

VII. Air starting systems (Transparencies 2 and 3)

  A. Air admission starting system--Compressed air admitted to engine cylinders to crank engine

  B. Air motor starting system--Compressed air turns motor which engages flywheel through a bendix drive

VIII. Components of a hydraulic starting system (Transparency 4)

  A. Reservoir

  B. Engine driven hydraulic pump

  C. Hand pump

  D. Pressure gauge

  E. Accumulator

INFORMATION SHEET

F. Pressure lines

G. Starter assembly

IX. Components of gasoline starting system

A. Gasoline engine

B. Clutch

C. Gear box

D. Drive pinion

X. Components of electric starting system

A. Lead acid storage batteries

B. Electric cranking motor

C. Starter switches

XI. Starting aids (Transparencies 5 and 6)

A. Special starting fluids

B. Heating coolant

C. Heating lubricating oil

D. Air heating engine

E. Heating intake air

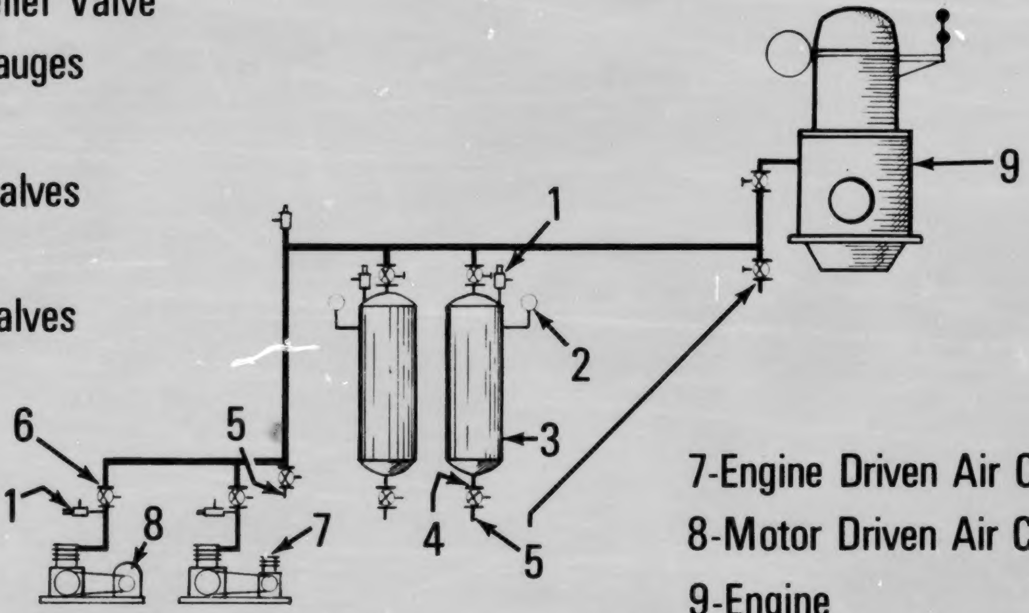
F. Glow plug

G. Heating starting battery

(NOTE: Aids may be used singly or in combination.)

Components of Air Admission Starting System

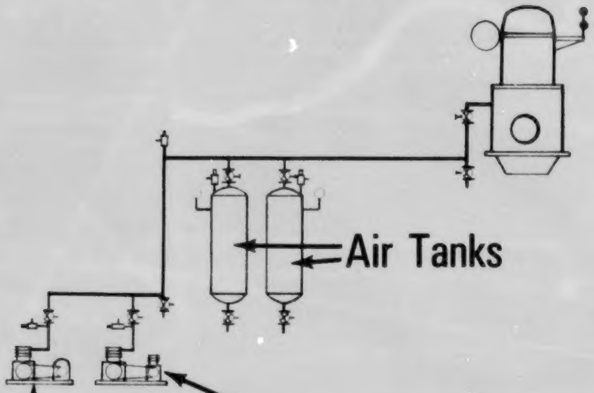
1-Pressure Relief Valve
2-Pressure Gauges
3-Air Tanks
4-Blow-Off Valves
5-Drain Line
6-Shut-Off Valves



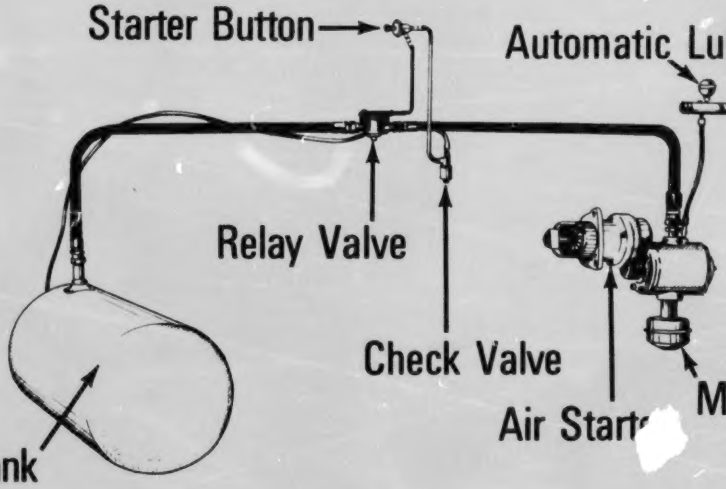
7-Engine Driven Air Compressor
8-Motor Driven Air Compressor
9-Engine

Air Starting Systems

Air Admission Starting System


Air Tanks
Motor Driven Air Compressor
Engine Driven Air Compressor

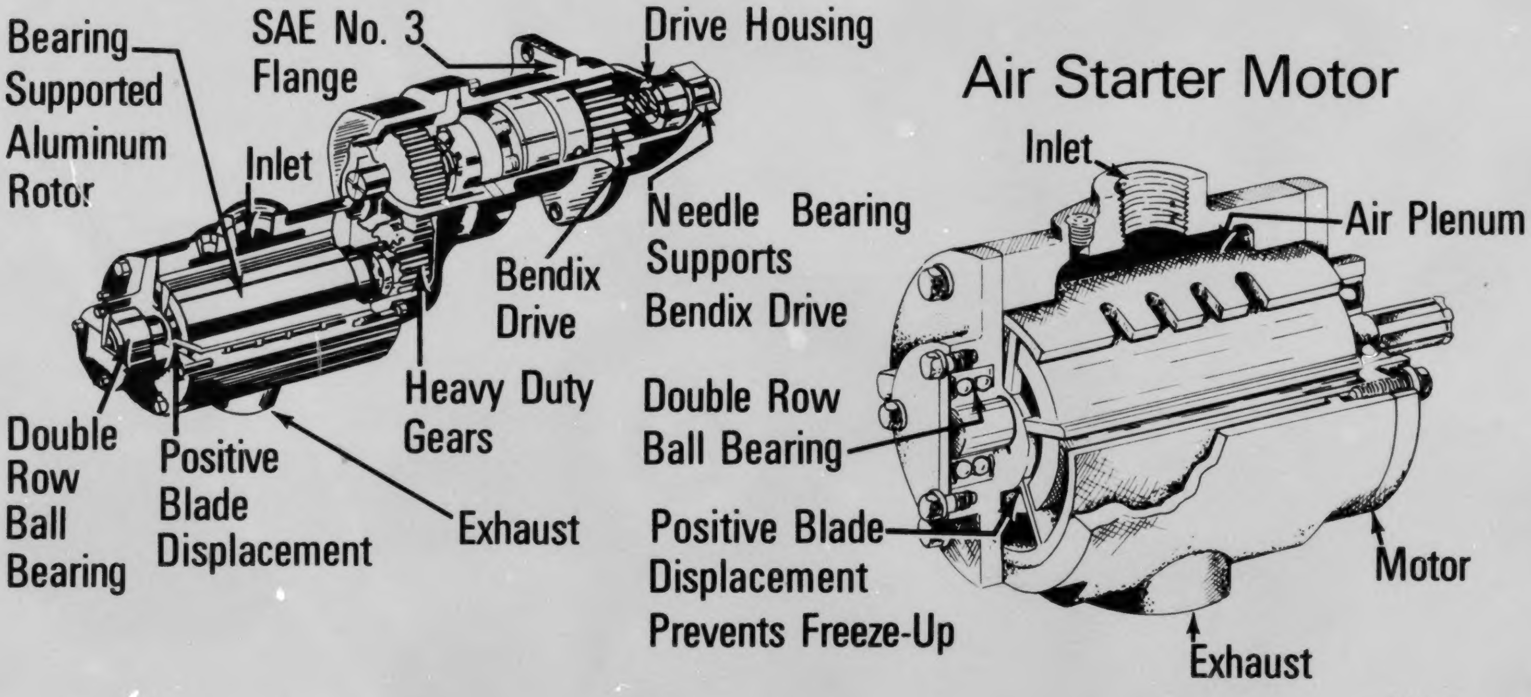
Air Motor Starting System


Starter Button
Automatic Lubricator
Relay Valve
Check Valve
Muffler
Air Start
Air Tank

Compressed Air Starting Motors

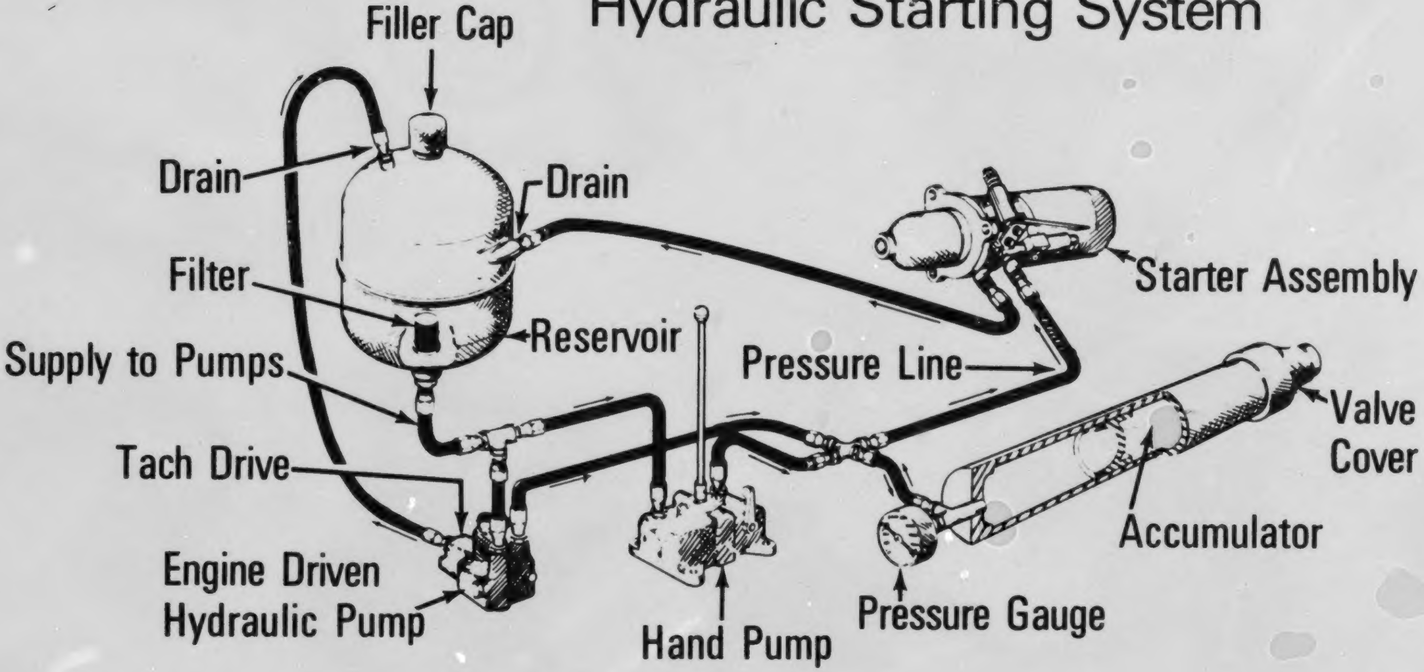
Highway Tractor Air Motor and Transmission Starter System

Air Starter Motor


Bearing Supported Aluminum Rotor
SAE No. 3 Flange
Drive Housing
Inlet
Needle Bearing Supports Bendix Drive
Bendix Drive
Heavy Duty Gears
Double Row Ball Bearing
Positive Blade Displacement
Exhaust
Inlet
Air Plenum
Double Row Ball Bearing
Positive Blade Displacement Prevents Freeze-Up
Motor
Exhaust

Components of Hydraulic Starting System

Hydraulic Starting System


Filler Cap
Drain
Drain
Filter
Reservoir
Supply to Pumps
Tach Drive
Engine Driven Hydraulic Pump
Hand Pump
Pressure Line
Starter Assembly
Pressure Gauge
Accumulator
Valve Cover

TM 4

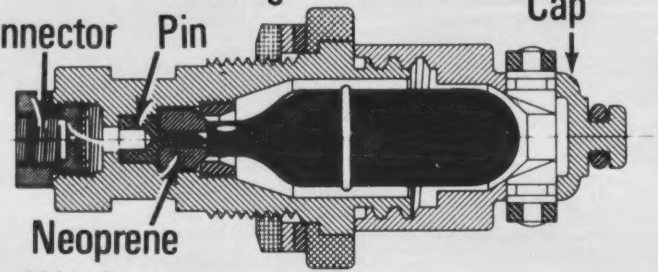
793

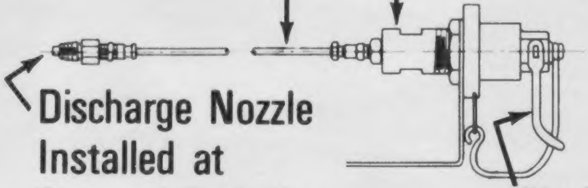
794

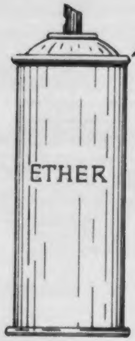
D:F - 173-D

Starting Aids

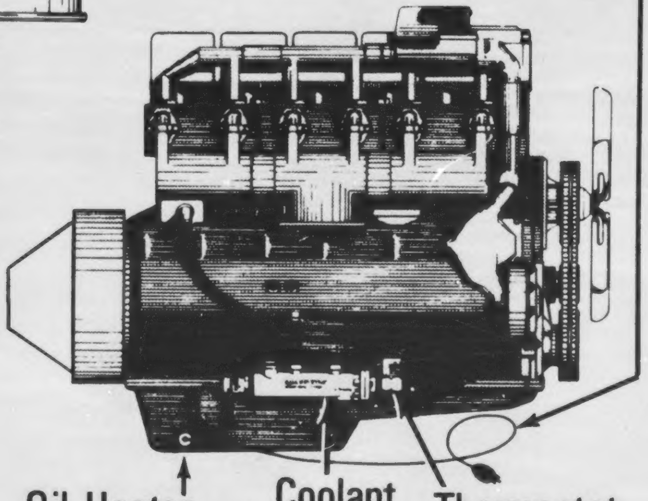
Ether Capsule Primer


Piercing Pin
Connector
Removable Cap
Neoprene Washer


Discharge Cell Mounted at Operator Station
3/16 in. O.D. Tubing
Discharge Nozzle Installed at Forward End of Intake Manifold
Discharge Lever


Aerosol Can of Ether
ETHER

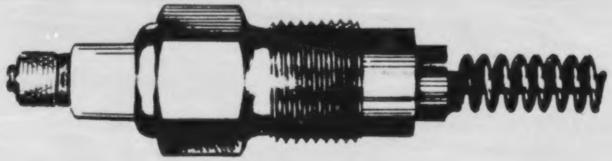
Electrically Heated

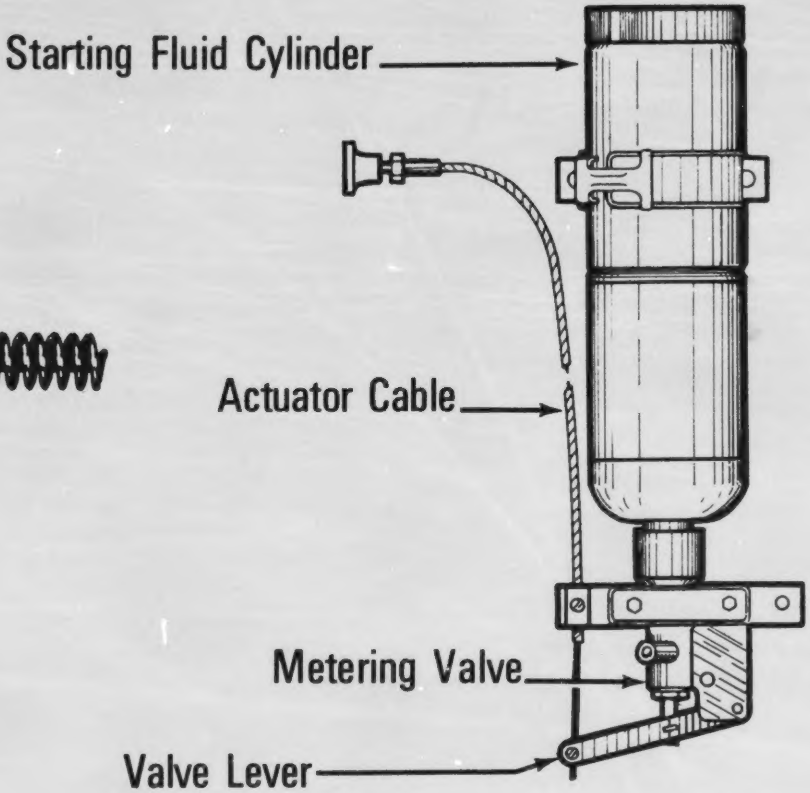

Oil Heater
Coolant Heater
Thermostat

Starting Aids

(Continued)

Typical Glow Plug




Starting Fluid Cylinder
Actuator Cable
Metering Valve
Valve Lever

STARTING SYSTEMS
UNIT IV

NAME ____________________________

TEST

1. Match the terms on the right with the correct definitions.

_____ a. A device used to store hydraulic energy under pressure for use in hydraulic cranking motor

_____ b. Gear with a small number of teeth designed to mesh with a larger gear

_____ c. Tendency of mass in motion to remain in motion, or if at rest, to remain at rest

_____ d. Dual, two systems

_____ e. Enclosed space

1. Inertia
2. Compound
3. Accumulator
4. Plenum
5. Pinion

2. Name four major types of starting systems.

a. ____________________________

b. ____________________________

c. ____________________________

d. ____________________________

3. Complete the following list of three sources of electricity that may be used in electric motor starting.

a. Twelve, twenty-four, or thirty-two volt storage batteries driving an electric starting motor

b. Sixty-four or one hundred ten volt storage batteries driving the ____________ ____________________________

c. Main switchboard in a stationary power plant where the switchboard is always ____________________________

4. List two sources of compressed air for compressed air starting motors.

a. ____________________________
b. ____________________________

5. Select true statements concerning how an engine is started by compressed air admission by placing an "X" in the appropriate blan[illegible]

_____a. Air is compressed in storage tanks

_____b. Compressed air is admitted through an automatic starting valve in engine cylinder head when the piston is at bottom center at start of the power stroke

_____c. Starting valve opening is timed by cams on the camshaft

6. Name five components of an air admission starting system.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

7. Distinguish between air admission and air motor starting systems by placing an "X" next to the description of an air admission starting system.

_____a. Compressed air admitted to engine cylinders to crank engine

_____b. Compressed air turns motor which engages flywheel through a bendix drive

8. Identify the components of a hydraulic starting system.

a. ____________________

b. ____________________

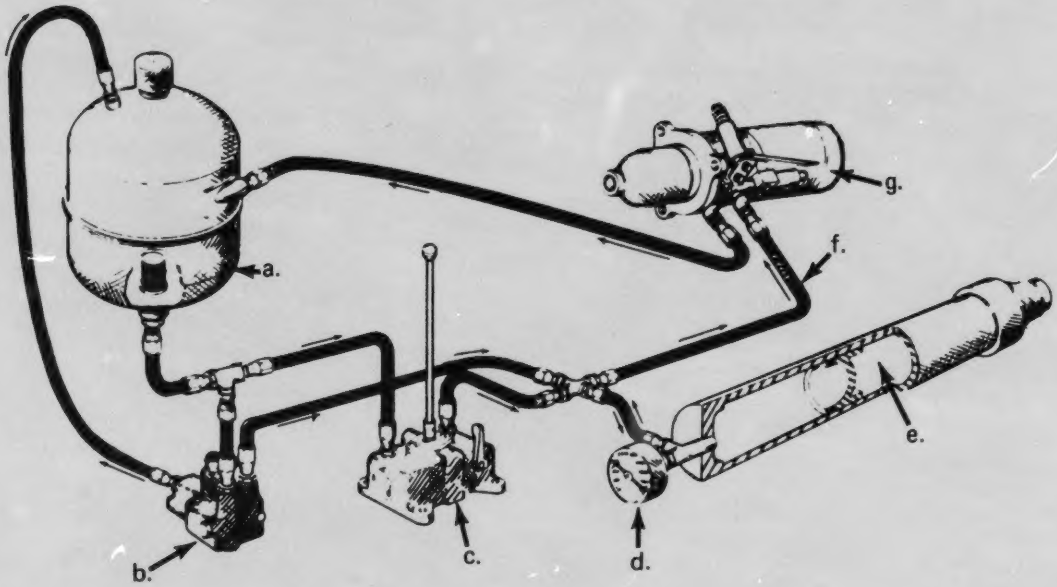
c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________



9. Name four components of a gasoline starting system.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

10. Name three components of an electric starting system.

a. ______________________________

b. ______________________________

c. ______________________________

11. Complete the following list of low temperature starting aids.

a. Special starting fluids

b. ______________________________

c. Heating lubricating oil

d. Air heating engine

e. ______________________________

f. ______________________________

g. Heating starting battery

STARTING SYSTEMS
UNIT IV

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 1
   d. 2
   e. 4

2. a. Hydraulic cranking motors
   b. Electric motors
   c. Gasoline engines
   d. Compressed air cranking systems

3. b. Main generator as a starting motor
   c. Energized

4. a. Separate engine and compressor
   b. Air brake compressor on highway diesel tractors

5. a, c

6. Any five of the following:

   a. Pressure relief valve
   b. Pressure gauges
   c. Air tanks
   d. Blow-off valves
   e. Drain valves
   f. Shut-off valves
   g. Engine driven air compressor
   h. Motor driven air compressor

7. a

8. a. Reservoir
   b. Engine driven hydraulic pump
   c. Hand pump
   d. Pressure gauge
   e. Accumulator
   f. Pressure lines
   g. Starter assembly

9. a. Gasoline engine
   b. Clutch
   c. Gear box
   d. Drive pinion

10. a. Lead acid storage batteries
    b. Electric cranking motor
    c. Starter switches

11. b. Heating coolant
    e. Heating intake air
    f. Glow plug

ENGINE BRAKES AND RETARDERS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to explain how the Jacobs engine brake system works. The student should also be able to demonstrate the ability to adjust a Jacobs engine brake, install a Jacobs engine brake, and adjust a slave piston on a Jacobs engine brake. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to engine brakes and retarders with the correct definitions.
2. Select true statements concerning the Jacobs engine brake operation in unit type injector systems.
3. Complete a list of troubleshooting procedures for the Jacobs engine brake.
4. Complete a list of advantages of the Jacobs engine brake.
5. Select true statements concerning the operation of the Brakesaver.
6. Demonstrate the ability to:
    a. Adjust a Jacobs engine brake on a Detroit diesel.
    b. Remove Brakesaver on a Caterpillar diesel engine.
    c. Disassemble a Brakesaver.
    d. Assemble a Brakesaver.
    e. Install a Brakesaver.
    f. Install a Jacobs engine brake on a Mack diesel.
    g. Adjust slave piston on a Jacobs engine brake on a Mack diesel.

ENGINE BRAKES AND RETARDERS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Dicuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Discuss troubleshooting of a Jacobs engine brake system.

VIII. Show a Jacobs engine brake system in operation.

IX. Take a field trip to a truck repair shop.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Jacobs Engine Brake Wiring Diagram
    2. TM 2--Jacobs Engine Brake on a Detroit Diesel
    3. TM 3--Jacobs Engine Brake on a Cummins (NH) Diesel
    4. TM 4--Jacobs Engine Brake on a Mack Diesel
    5. TM 5--Brakesaver
    6. TM 6--Oil Flow Through Brakesaver
  D. Job sheets
    1. Job Sheet #1--Adjust a Jacobs Engine Brake on a Detroit Diesel
    2. Job Sheet #2--Remove Brakesaver on a Caterpillar Diesel Engine

3. Job Sheet #3--Disassemble a Brakesaver

4. Job Sheet #4--Assemble a Brakesaver

5. Job Sheet #5--Install a Brakesaver

6. Job Sheet #6--Install a Jacobs Engine Brake on a Mack Diesel

7. Job Sheet #7--Adjust Slave Piston on a Jacobs Engine Brake on a Mack Diesel

E. Test

F. Answers to test

II. References:

A. Forier, Louis C. *Motor Trucks and Diesel Repair Manual.* 33rd Edition. New York, NY 10010: Motor, 1980.

B. *Bulletin No. 3379076-92 Cummins Engine Shop Manual.* Columbus, IN: Cummins Engine Company, Inc., 1977.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

D. *Service Manual: 3406 Industrial and Marine Engine.* Caterpillar Tractor Company, 1979.

ENGINE BRAKES AND RETARDERS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Exhaust brake--Uses a valve in the exhaust which keeps the exhaust gases backed up in the exhaust manifold

B. Air suppressor--Stops air pulsations

C. Slave piston--Operates exhaust valves

D. Master piston--Supplies high pressure oil to slave piston

E. Clutch switch--Disengages compression brake

F. Engine brake--Device used to convert the engine into a compressor or air pump, thus effectively braking the vehicle

G. Engine retarder--Device used to convert the engine into a compressor or air pump, thus effectively slowing the engine down

II. Jacobs engine brake operation in unit type injector systems

A. Driver operates an electrical switch (Transparency 1)

B. A solenoid valve permits lubricating oil to flow under pressure through the slave piston control valve to both the master piston and slave piston

C. Oil pressure causes the master piston to move down, coming to rest on the injector rocker arm adjusting screw

(NOTE: Some systems do not have rocker arms.)

D. The injector rocker arm adjusting screw begins upward travel forcing the master piston upward and creating a high pressure oil flow to the slave piston

E. The ball check valve in the control valve imprisons high pressure oil in the master-slave piston system

F. The slave piston under the influence of high pressure oil flow moves down, momentarily opening the exhaust valve, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold

G. Compressed air escapes into the atmosphere, completing a compression braking cycle; after piston starts down on power stroke and all valves are closed; this creates a vacuum

INFORMATION SHEET

III. Troubleshooting the Jacobs engine brake

  A. Engine fails to start--Solenoid valves stuck in the open position

  B. Drop in engine lube oil pressure

    1. Oil inlet supply seal missing or damaged
    2. Upper solenoid valve seal missing or damaged
    3. Fuel line leakage

    (NOTE: This applies only to DD engine.)

  C. One or two cylinders fail to brake

    1. Slave piston control valve stuck in "Off" position
    2. Slave piston control valve failure
    3. Slave piston adjustment incorrect
    4. Engine brake housing oil connector or seals leaking

  D. Solenoids won't control brake operation--Center solenoid valve seal missing or damaged

  E. Solenoids will not energize

    1. Blown fuse
    2. Automatic switches fail to close
    3. Incorrect electrical power source

  F. Engine brake slow to operate

    1. Lube oil cold and/or too thick
    2. Lower solenoid valve seal missing or damaged
    3. Solenoid valve filter screen clogged
    4. Control valves binding in housing
    5. Switch operation sluggish
    6. Incorrect adjustments

  G. One or more cylinders fail to stop braking or engine stalls

    1. One or more slave piston control valves stuck in "On" postion
    2. Solenoid valve sticking in "On" position

INFORMATION SHEET

3. Center solenoid valve seal missing or damaged
4. Solenoid valve exhaust plugged
5. Switch stuck in "On" position or misadjusted
6. Buffer switch set too tight

IV. Advantages of the Jacobs engine brake

A. Brake lining and brake drum life is extended up to five times that obtained without the Jacobs engine brake

B. The ability of the brake to maintain engine operating temperatures on down hill grades and the possibility that the frequency of valve setting can be reduced, all lend a hand in lowering overall maintenance costs of diesel vehicle operation

C. A minimum amount of labor is required for installation with very little service needed

D. The elimination of continual braking with vehicle service brakes and the resulting reduction of heat add considerably to tire life and wear

E. Shorter round trip schedules can be obtained through use of the engine brake, providing valuable extra hours

V. Operation of the Brakesaver (Transparency 2)

A. The rotor is fastened to and turns with the engine crankshaft; the rotor has pockets on the outer circumference of both sides and four holes to permit equal flow to both sides of the rotor (Transparencies 3 and 4)

B. The housing and stator are fastened to the flywheel housing and cannot turn, and both have pockets on their inside surfaces in alignment with the pockets in the motor (Transparencies 3 and 4)

C. The rotor turns in the compartment made by the stator and the Brakesaver housing

D. When housing is in operation, engine oil comes in near center from a passage at bottom of the housing (Transparency 6)

E. The rotor turns with crankshaft and throws this oil outward; the shape of the rotor pockets send it into the pockets of the stator and housing

F. As the rotor turns and oil flows around the Brakesaver compartment, it takes the shape of a spiral

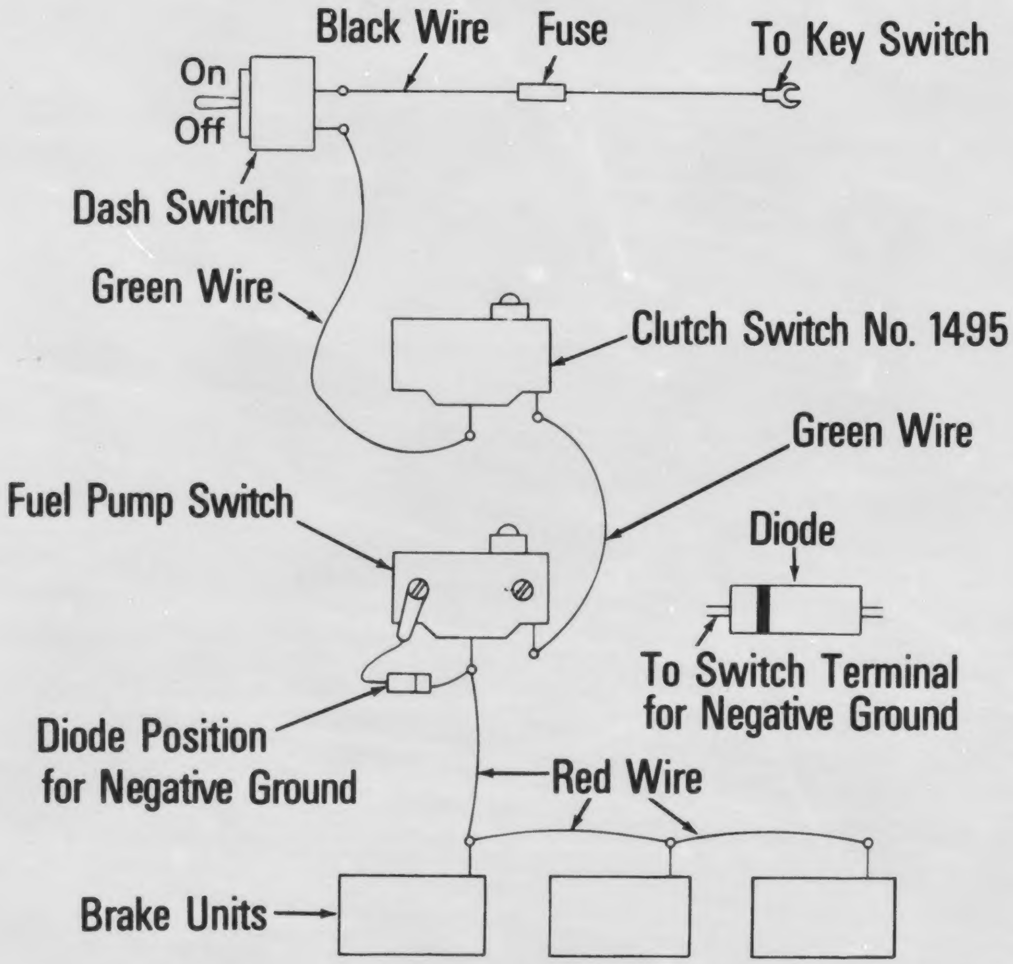
G. The oil flow is constantly cut by the vanes of the rotor; this cutting action gives resistance to the oil

INFORMATION SHEET

H. When Brakesaver is in operation, the level of braking can be controlled by the inlet oil pressure, since the amount of oil is cut by the rotor vanes

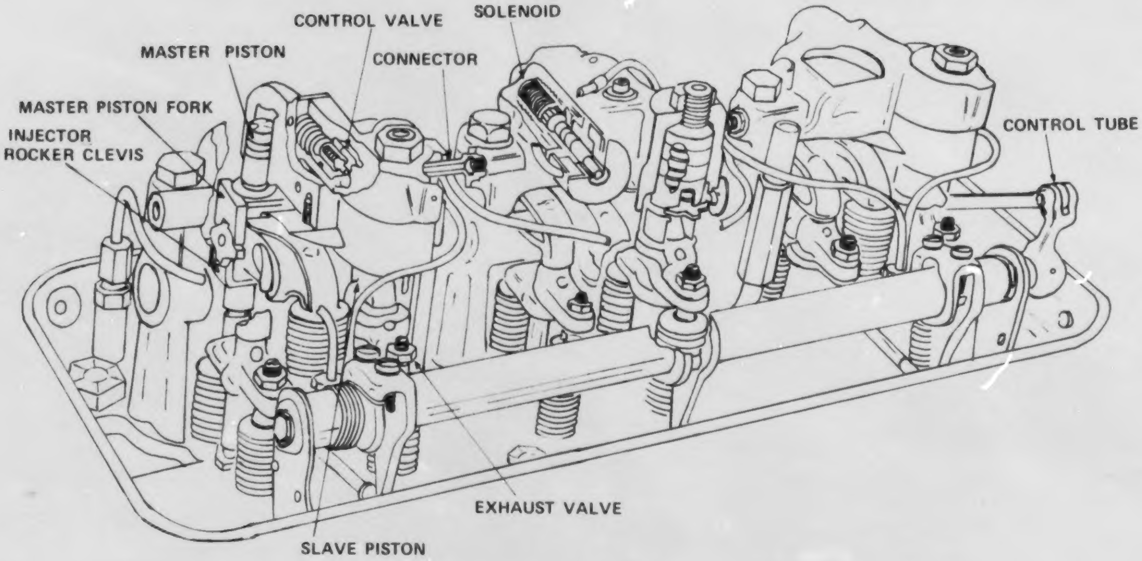
I. When Brakesaver is not in operation, the inlet passage to the rotor is closed by the control valve, and there is no oil in the Brakesaver compartment

Jacobs Engine Brake Wiring Diagram

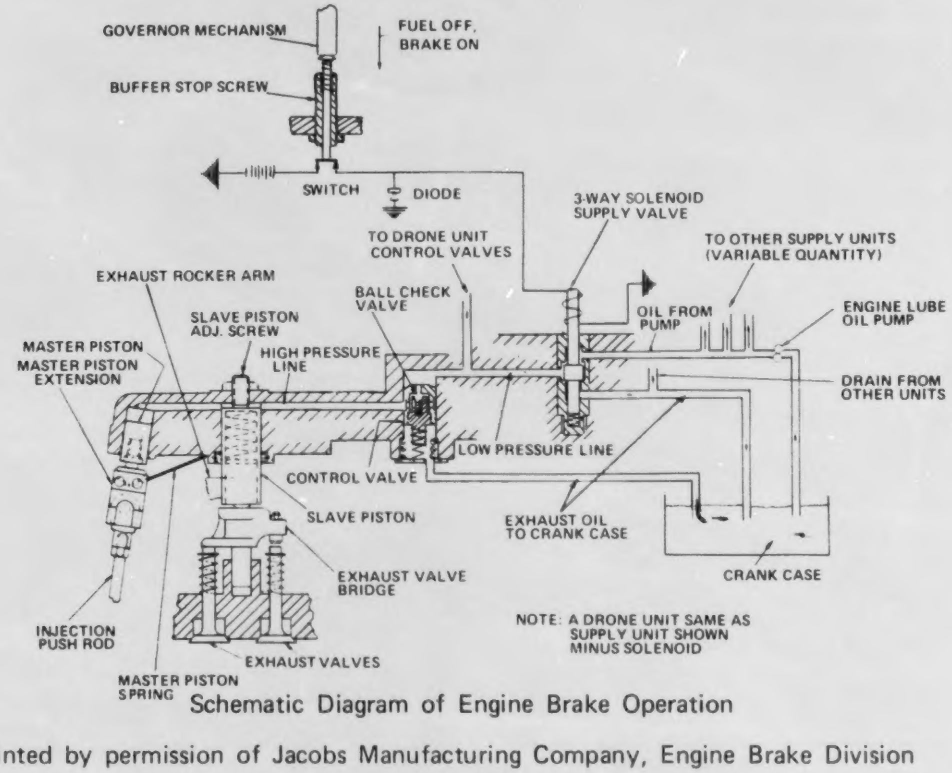

Black Wire
Fuse
To Key Switch
On
Off
Dash Switch
Green Wire
Clutch Switch No. 1495
Green Wire
Fuel Pump Switch
Diode
To Switch Terminal for Negative Ground
Diode Position for Negative Ground
Red Wire
Brake Units

Courtesy of Cummins Engine Company, Inc.

Jacobs Engine Brake on a Detroit Diesel


CONTROL VALVE
SOLENOID
MASTER PISTON
CONNECTOR
MASTER PISTON FORK
INJECTOR
ROCKER CLEVIS
CONTROL TUBE
EXHAUST VALVE
SLAVE PISTON

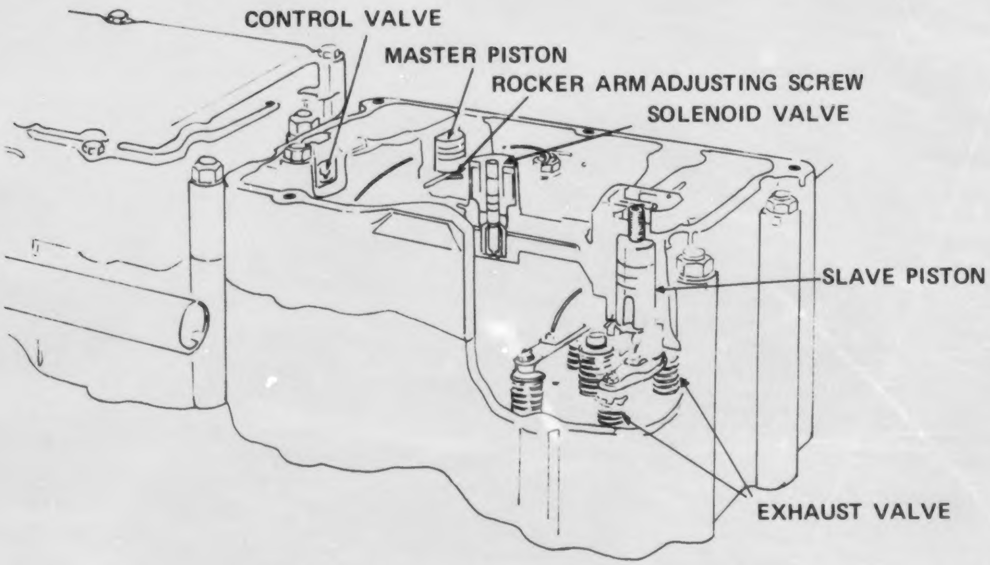
Engine Brake Cutaway


GOVERNOR MECHANISM
FUEL OFF,
BRAKE ON
BUFFER STOP SCREW
SWITCH
DIODE
3-WAY SOLENOID
SUPPLY VALVE
TO DRONE UNIT
CONTROL VALVES
TO OTHER SUPPLY UNITS
(VARIABLE QUANTITY)
EXHAUST ROCKER ARM
BALL CHECK
VALVE
OIL FROM
PUMP
ENGINE LUBE
OIL PUMP
SLAVE PISTON
ADJ. SCREW
MASTER PISTON
MASTER PISTON
EXTENSION
HIGH PRESSURE
LINE
DRAIN FROM
OTHER UNITS
LOW PRESSURE LINE
CONTROL VALVE
SLAVE PISTON
EXHAUST OIL
TO CRANK CASE
CRANK CASE
EXHAUST VALVE
BRIDGE
NOTE: A DRONE UNIT SAME AS
SUPPLY UNIT SHOWN
MINUS SOLENOID
INJECTION
PUSH ROD
EXHAUST VALVES
MASTER PISTON
SPRING

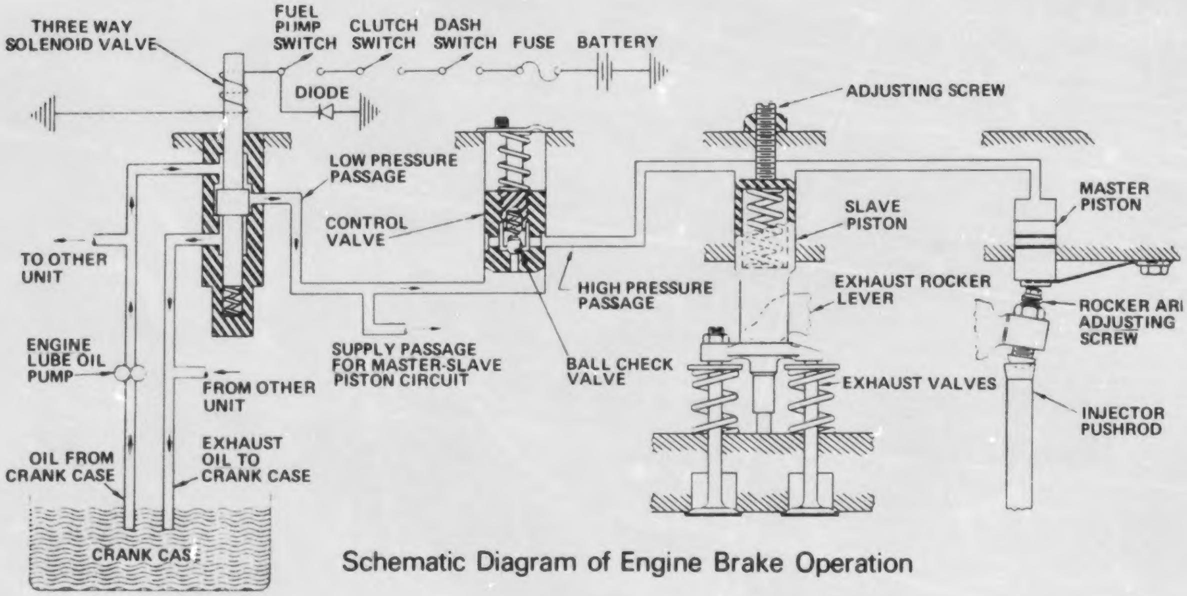
Schematic Diagram of Engine Brake Operation

Reprinted by permission of Jacobs Manufacturing Company, Engine Brake Division

Jacobs Engine Brake on a Cummins (NH) Diesel


CONTROL VALVE
MASTER PISTON
ROCKER ARM ADJUSTING SCREW
SOLENOID VALVE
SLAVE PISTON
EXHAUST VALVE

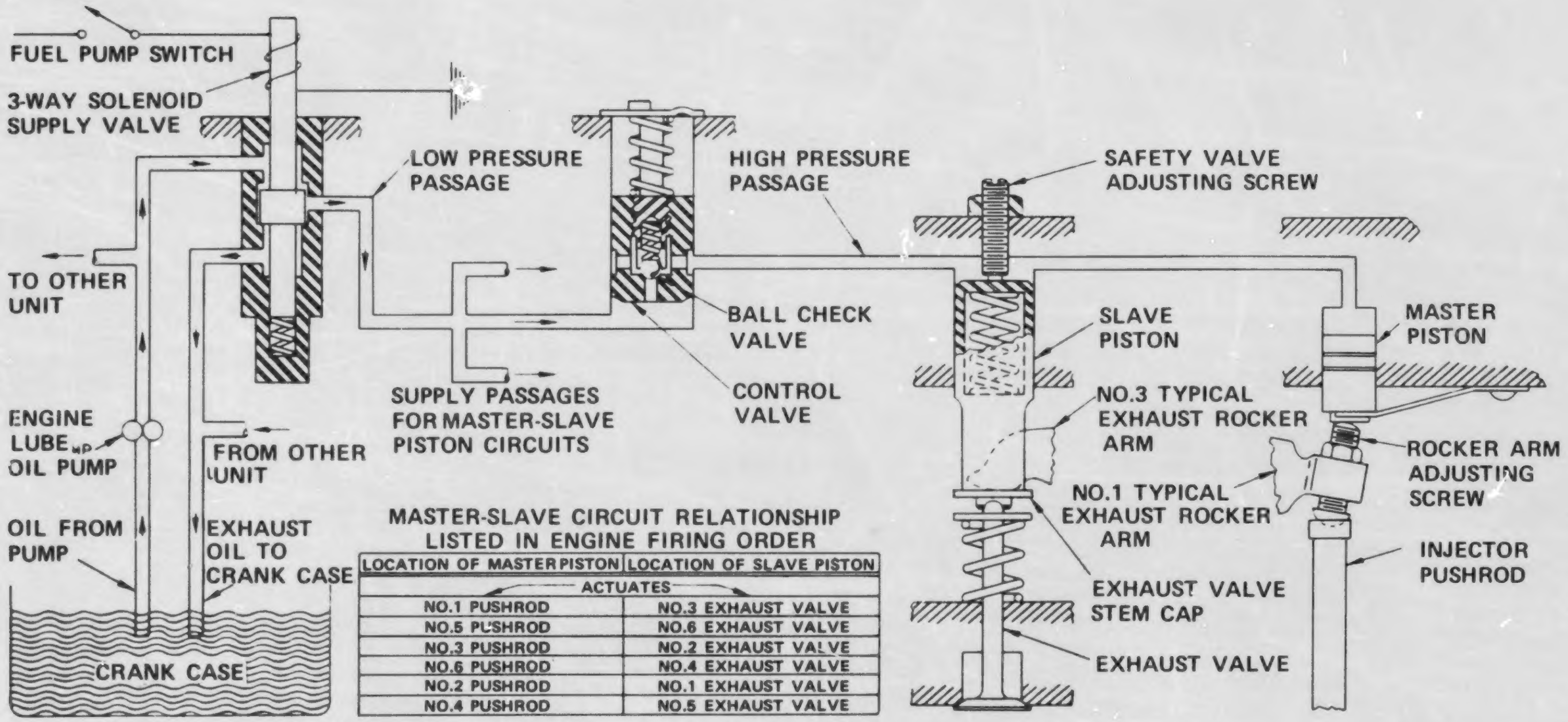
Engine Brake Cutaway


THREE WAY SOLENOID VALVE
FUEL PUMP SWITCH
CLUTCH SWITCH
DASH SWITCH
FUSE
BATTERY
DIODE
ADJUSTING SCREW
LOW PRESSURE PASSAGE
CONTROL VALVE
MASTER PISTON
SLAVE PISTON
TO OTHER UNIT
HIGH PRESSURE PASSAGE
EXHAUST ROCKER LEVER
ROCKER ARI ADJUSTING SCREW
ENGINE LUBE OIL PUMP
SUPPLY PASSAGE FOR MASTER-SLAVE PISTON CIRCUIT
BALL CHECK VALVE
FROM OTHER UNIT
EXHAUST VALVES
INJECTOR PUSHROD
OIL FROM CRANK CASE
EXHAUST OIL TO CRANK CASE
CRANK CASE

Schematic Diagram of Engine Brake Operation

Reprinted by permission of Jacobs Manufacturing Company, Engine Brake Division

Jacobs Engine Brake on a Mack Diesel


FUEL PUMP SWITCH
3-WAY SOLENOID SUPPLY VALVE
TO OTHER UNIT
ENGINE LUBE OIL PUMP
OIL FROM PUMP
CRANK CASE
FROM OTHER UNIT
EXHAUST OIL TO CRANK CASE
LOW PRESSURE PASSAGE
SUPPLY PASSAGES FOR MASTER-SLAVE PISTON CIRCUITS
HIGH PRESSURE PASSAGE
BALL CHECK VALVE
CONTROL VALVE
SAFETY VALVE ADJUSTING SCREW
SLAVE PISTON
NO.3 TYPICAL EXHAUST ROCKER ARM
NO.1 TYPICAL EXHAUST ROCKER ARM
EXHAUST VALVE STEM CAP
EXHAUST VALVE
MASTER PISTON
ROCKER ARM ADJUSTING SCREW
INJECTOR PUSHROD

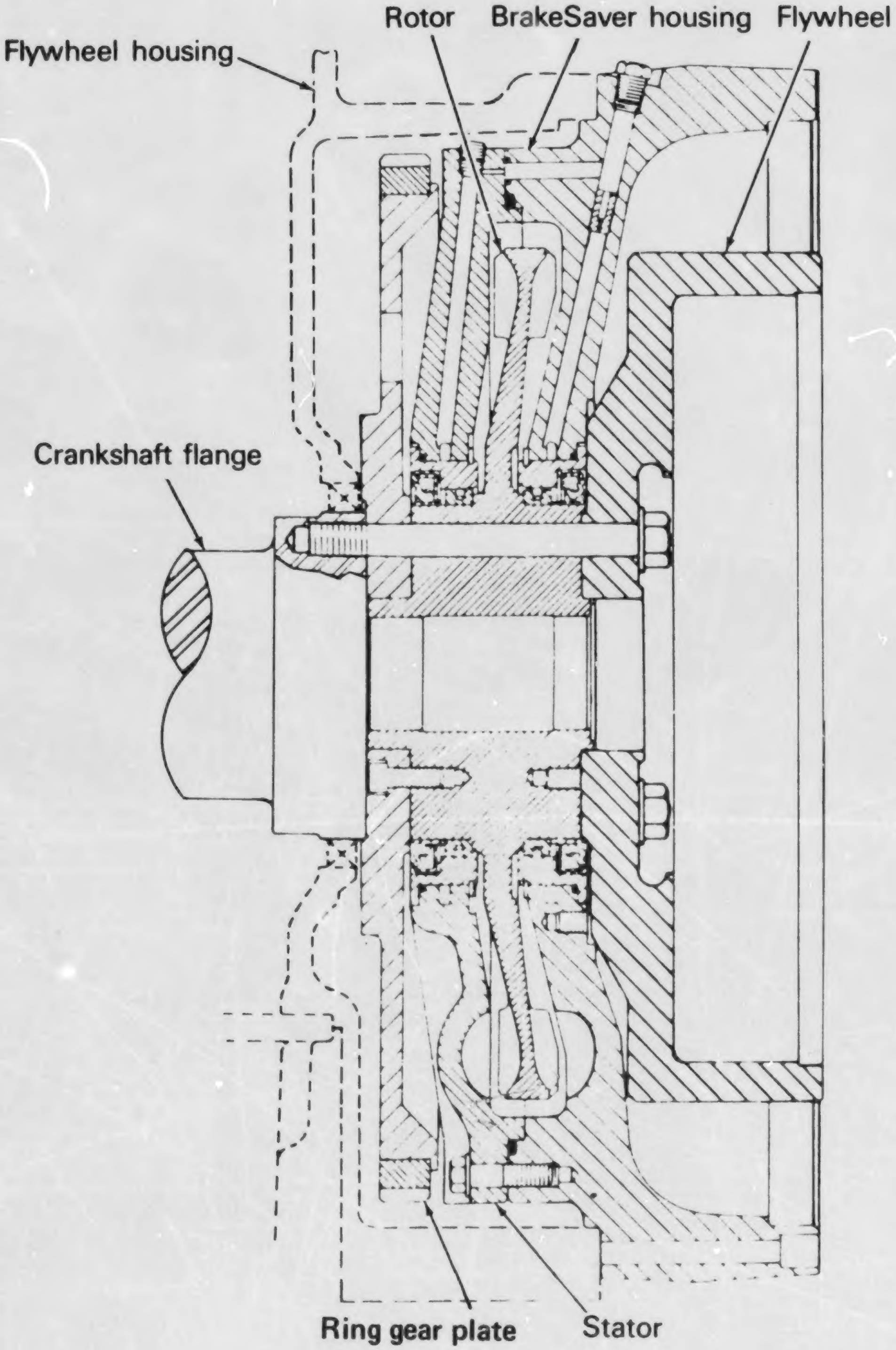
MASTER-SLAVE CIRCUIT RELATIONSHIP LISTED IN ENGINE FIRING ORDER

LOCATION OF MASTER PISTON	LOCATION OF SLAVE PISTON
ACTUATES	
NO.1 PUSHROD	NO.3 EXHAUST VALVE
NO.5 PUSHROD	NO.6 EXHAUST VALVE
NO.3 PUSHROD	NO.2 EXHAUST VALVE
NO.6 PUSHROD	NO.4 EXHAUST VALVE
NO.2 PUSHROD	NO.1 EXHAUST VALVE
NO.4 PUSHROD	NO.5 EXHAUST VALVE

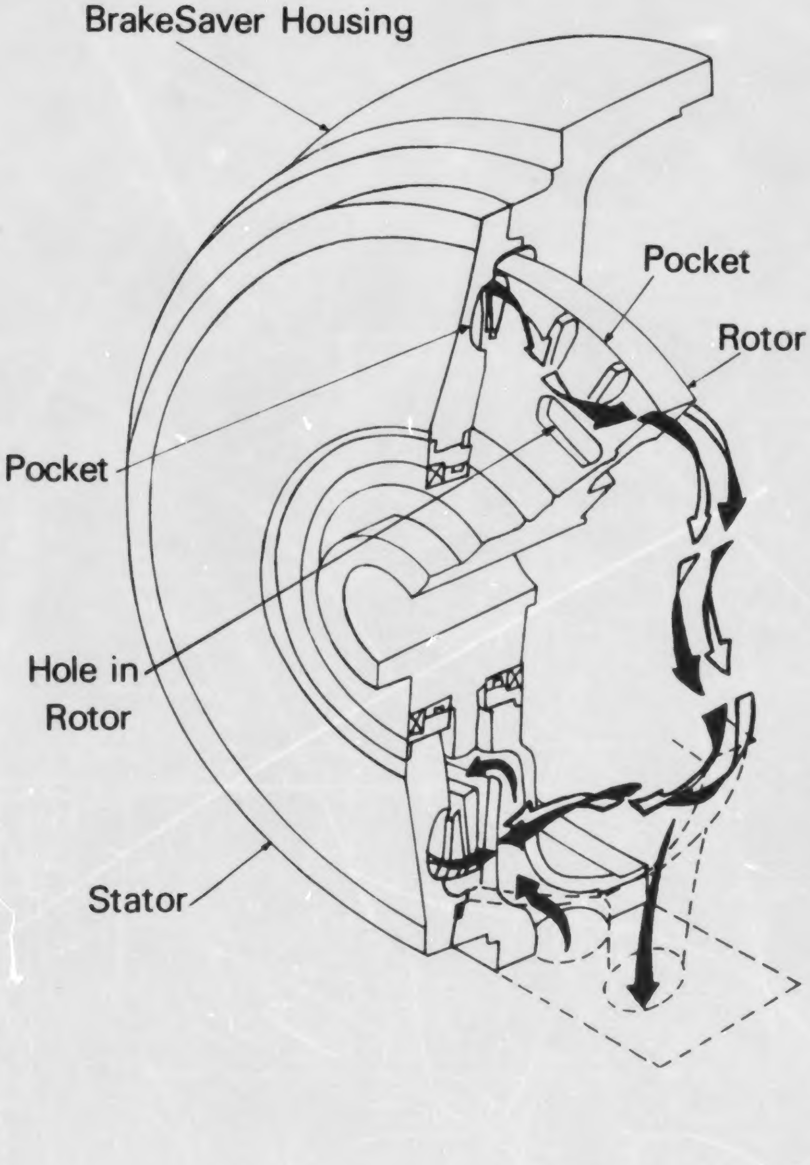
Typical Master Slave Circuit

Reprinted by permission of Jacobs Manufacturing Company, Engine Brake Division

BrakeSaver


Rotor
BrakeSaver housing
Flywheel
Flywheel housing
Crankshaft flange
Ring gear plate
Stator

Oil Flow Through BrakeSaver


BrakeSaver Housing
Pocket
Rotor
Pocket
Hole in Rotor
Stator

817

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #1--ADJUST A JACOBS ENGINE BRAKE ON A DETROIT DIESEL

I. Tools and materials:

   A. Basic hand tools

   B. Appropriate service manual

   C. Clean shop towels

   D. Safety glasses

   E. Detroit diesel engine with Jacobs engine brake

II. Procedure

(CAUTION: Follow all shop safety procedures.)

   A. Adjust slave piston model 20

      1. Loosen and back off locknut

      2. Use a feeler gauge and back off slave piston adjusting screw until piston spring lets go of adjusting screw

         (NOTE: Valve piston will move up into housing under influence of its spring until it seats in its bore, removing spring load from adjusting screw.)

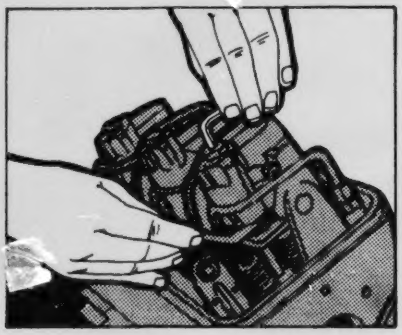
      3. Bring the engine to normal operating temperature

      4. Set engine idle to 550 rpm

JOB SHEET #1

5. Turn adjusting screw down slowly until slave piston contacts the crosshead as indicated by the twitch in the handle of the Allen wrench (Figure 1)

FIGURE 1



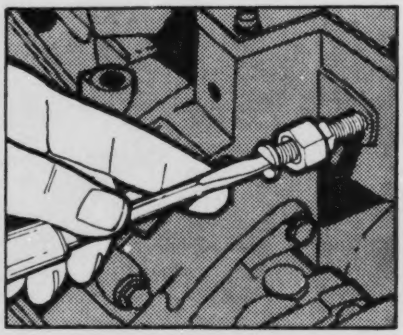
Reprinted from MOTOR Truck and Diesel Repair Manual by permission of The Hearst Corporation, Copyright 1981.

(NOTE: Do not attempt to make this adjustment by holding the locknut and turning the adjusting screw through both the locknut and the brake housing.)

6. Back the adjusting screw out exactly 1/2 turn and tighten locknut

B. Adjust buffer screw models 53A and 71 (Figure 2)

FIGURE 2



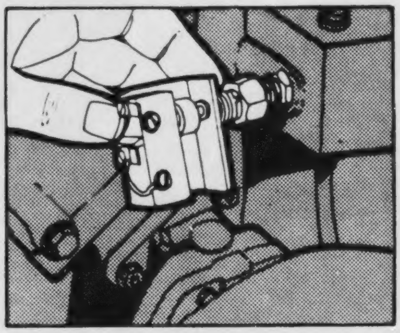
Reprinted from MOTOR Truck and Diesel Repair Manual by permission of The Hearst Corporation, Copyright 1981.

1. Start the engine
2. Adjust the buffer screw to stop governor hunting at idle speed
3. Do not increase engine speed above normal idle by forcing buffer screw past the point where governor hunt has been eliminated
4. Tighten lock nut

JOB SHEET #1

5. Attach buffer switch to buffer screw and position switch to clear other engine components (Figure 3)

FIGURE 3



Reprinted from MOTOR Truck and Diesel Repair Manual by permission of The Hearst Corporation, Copyright 1981.

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #2--REMOVE BRAKESAVER ON A CATERPILLAR DIESEL ENGINE

I. Tools and materials

- A. Basic hand tools
- B. Appropriate service manual
- C. Shop towels
- D. Safety glasses
- E. Caterpillar engine with Brakesaver

II. Procedure

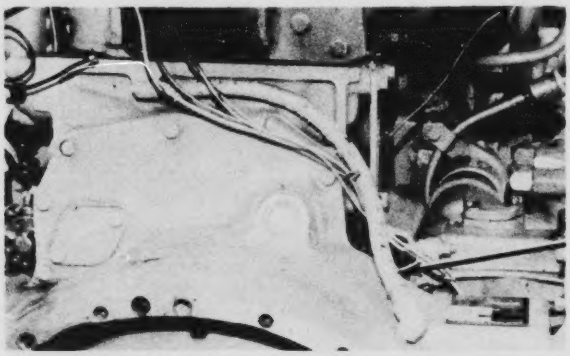
(CAUTION: Follow all shop safety procedures.)

A. Remove transmission from vehicle as specified in manual

(NOTE: When removing transmission be sure that ground cable is removed from battery and a tag is on starting switch.)

B. Disconnect the lubrication oil line from the fitting at the top of Brakesaver housing (Figure 1)

FIGURE 1

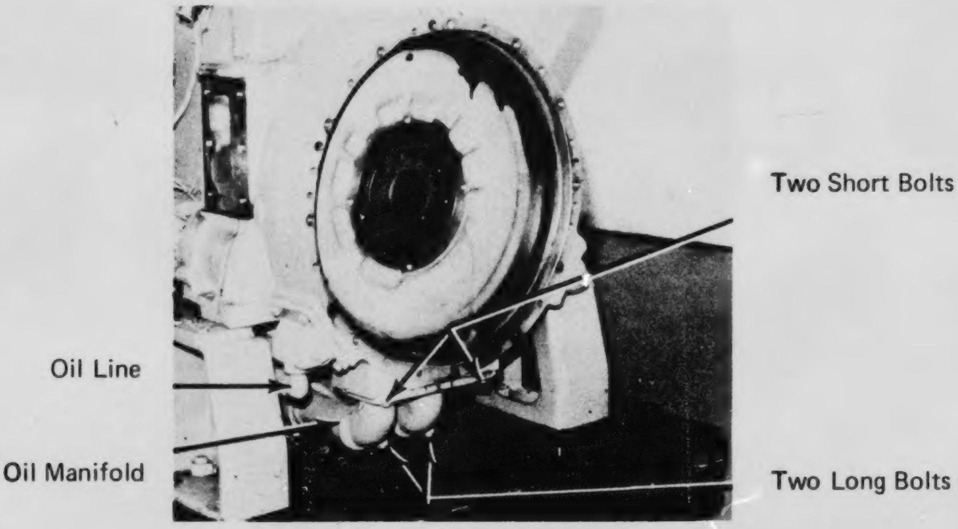


Lubrication Line

JOB SHEET #2

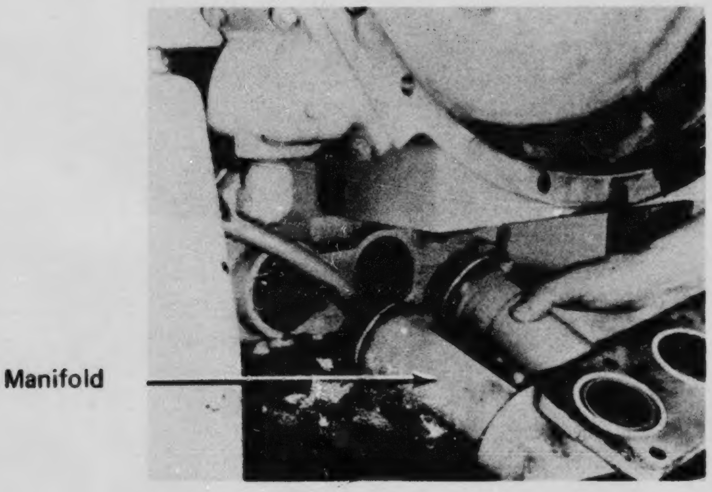
C. Disconnect the oil line at the bottom of the Brakesaver housing (Figure 2)

FIGURE 2


Two Short Bolts
Oil Line
Oil Manifold
Two Long Bolts

D. Remove the two short bolts and two longer bolts that hold oil manifold to Brakesaver housing, and remove the manifold from the Brakesaver control valve (Figures 2 and 3)

FIGURE 3

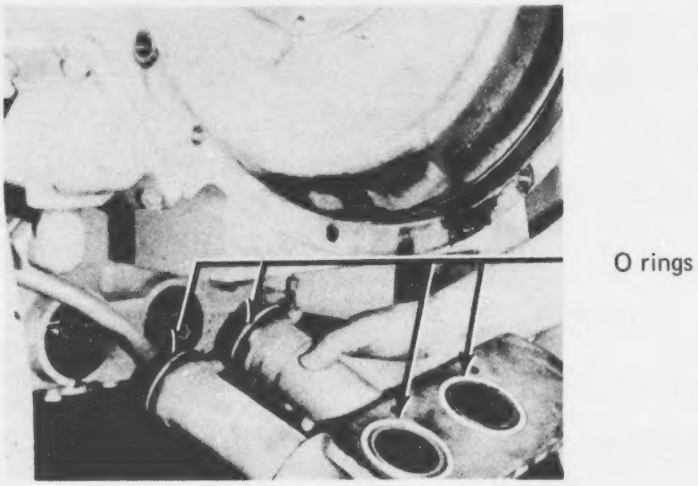


(NOTE: The two longer bolts from the manifold can be used as forcing screws to remove the Brakesaver from the flywheel housing.)

JOB SHEET #2

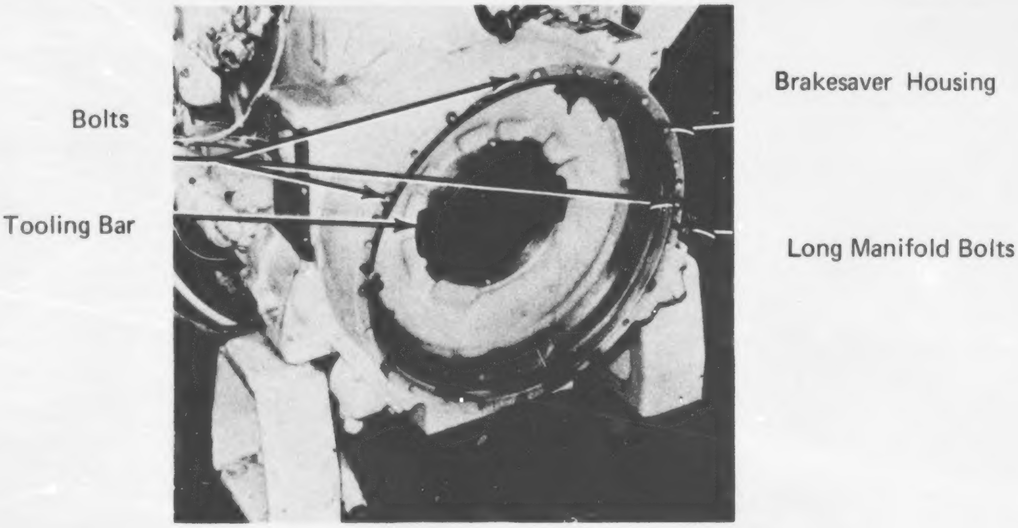
E. Remove the O-ring seals from the manifold (Figure 4)

FIGURE 4



F. Install an eye bolt in the top of the Brakesaver housing and fasten a hoist, and install tool on the Brakesaver housing and rotor (Figure 5)

FIGURE 5

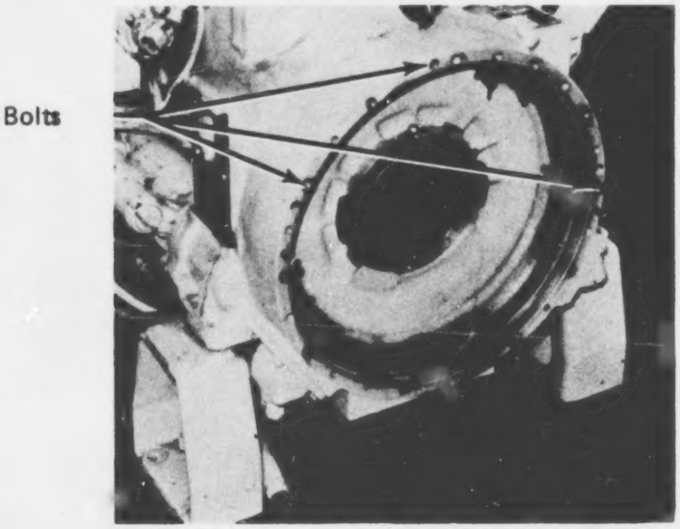

Bolts
Tooling Bar
Brakesaver Housing
Long Manifold Bolts

(NOTE: The tool holds the Brakesaver housing and rotor assembly together, while removing; this prevents damage to the rotor rings and seals.)

JOB SHEET #2

G. Remove bolts that hold Brakesaver housing to the flywheel housing (Figure 6)

FIGURE 6



(NOTE: Use long bolts from manifold as forcing screws and tighten the bolts evenly to remove the Brakesaver housing from the flywheel housing.)

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #3--DISASSEMBLE A BRAKESAVER

I. Tools and materials

   A. Basic hand tools

   B. Appropriate service manual

   C. Puller set

   D. Shop towels

   E. Safety glasses

   F. Brakesaver assembly

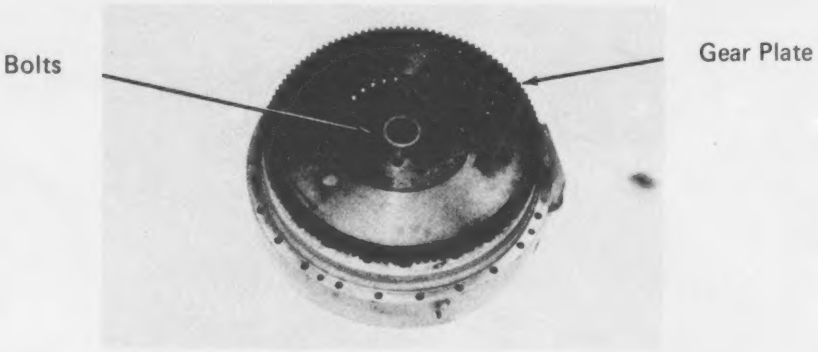
II. Procedure

(CAUTION: Follow all shop safety procedures.)

   A. Remove the tool holding the Brakesaver housing and rotor together

   B. Remove bolts from gear plate and remove the plate (Figure 1)

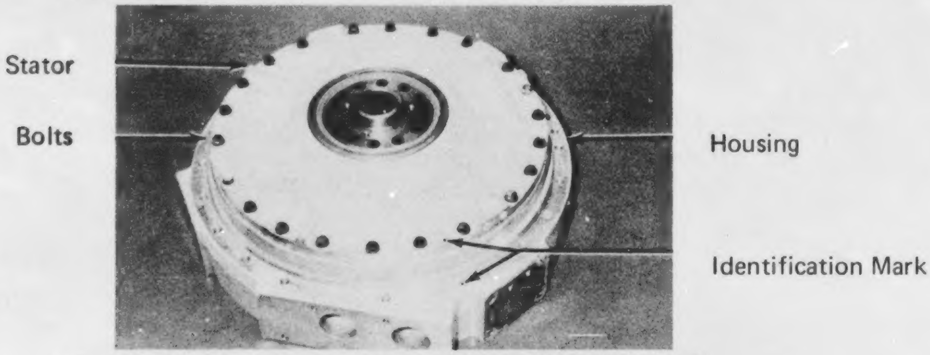
FIGURE 1



JOB SHEET #3

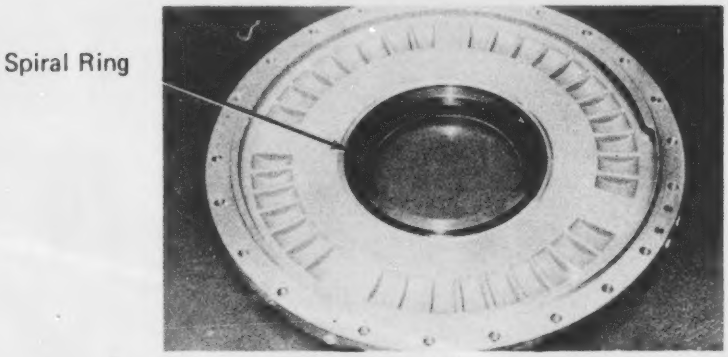
C. Make identification as to the location of stator with housing, and remove bolts and the stator (Figure 2)

FIGURE 2


Stator
Bolts
Housing
Identification Mark

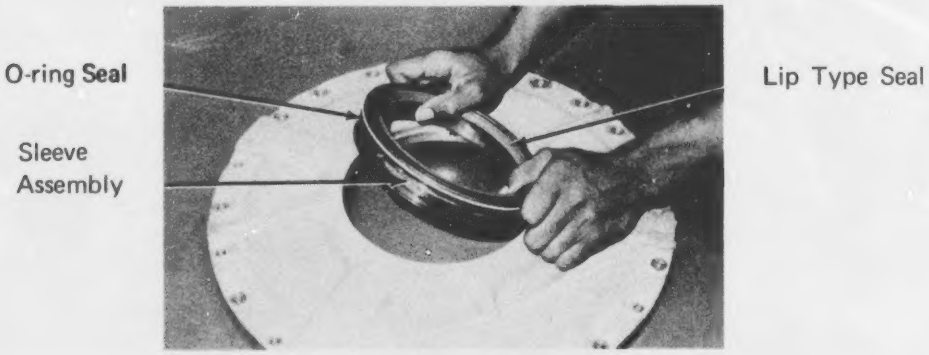
D. **Turn the stator over and remove spiral ring (Figure 3)**

FIGURE 3


Spiral Ring

E. **Turn the stator over again and remove sleeve assembly**, O-ring seal, and lip type seal from the sleeve (Figure 4)

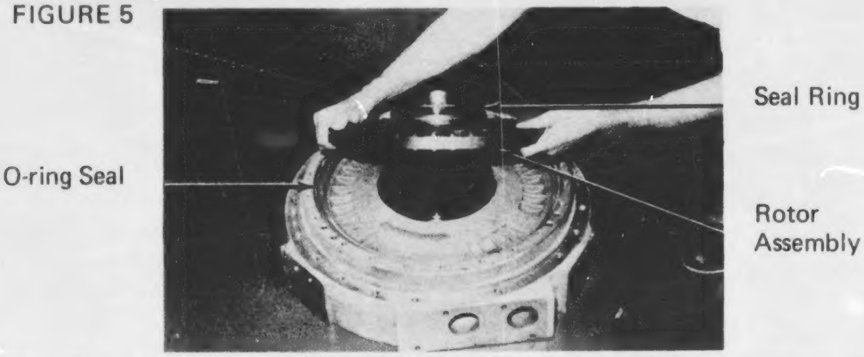
FIGURE 4


O-ring Seal
Sleeve Assembly
Lip Type Seal

JOB SHEET #3

F. Remove O-ring seal and the six smaller O-ring seals from the oil holes on the housing (Figure 5)

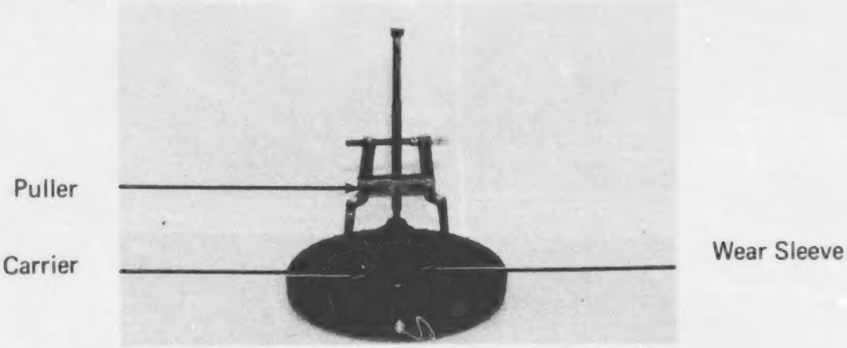
FIGURE 5


Seal Ring
O-ring Seal
Rotor Assembly

G. Remove rotor assembly and seal ring from both sides of the rotor (Figure 5)

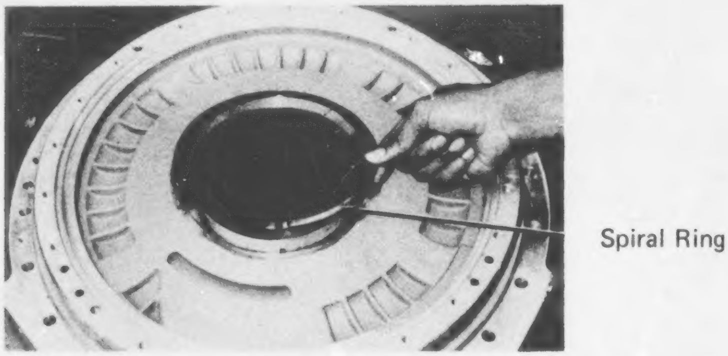
H. Remove carrier and wear sleeve with puller from both sides of the rotor (Figure 6)

FIGURE 6


Puller
Carrier
Wear Sleeve

I. Remove spiral ring (Figure 7)

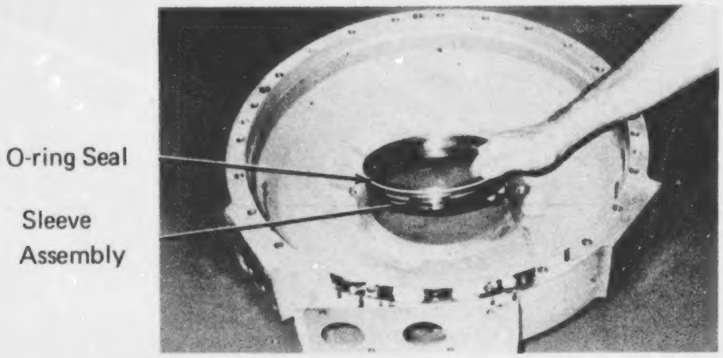
FIGURE 7


Spiral Ring

JOB SHEET #3

J. Turn the housing over and remove sleeve assembly, and remove the lip type seal and O-ring seal from the sleeve (Figure 8)

FIGURE 8


O-ring Seal
Sleeve Assembly

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #4--ASSEMBLE A BRAKESAVER

I. Tools and materials

- A. Basic hand tools
- B. Appropriate service manual
- C. Shop towels
- D. Seal installer set
- E. Safety glasses
- F. Brakesaver assembly

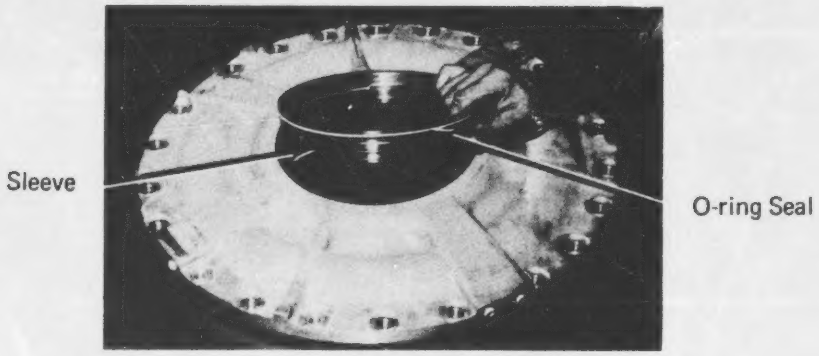
II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Inspect the O-ring seals for damage and make replacements if needed.)

A. Install O-ring seal on sleeve (Figure 1)

FIGURE 1



(NOTE: Put clean oil on the O-ring seals while installing.)

B. Install the sleeve in the Brakesaver housing, and make sure the notch in the sleeve is aligned with the notch in the housing and install the dowel

(CAUTION: Make certain there is clearance behind the spiral ring when it is correctly installed.)

C. Turn the housing over and install the spiral ring that holds the sleeve in the housing

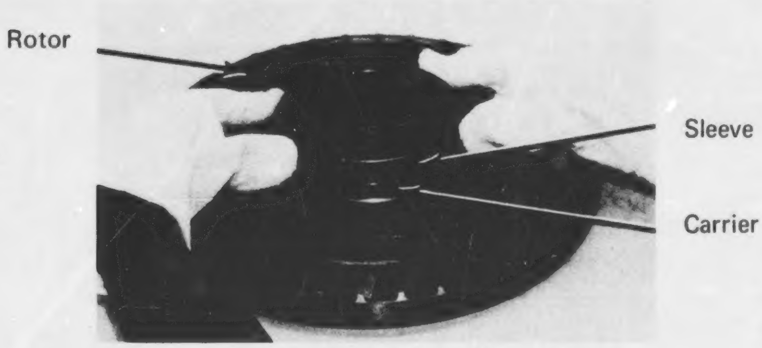
JOB SHEET #4

D. Heat the carriers and the wear sleeves to a maximum temperature of 300°F

(NOTE: Make sure the carrier is at bottom on the rotor and sleeve is against the carrier.)

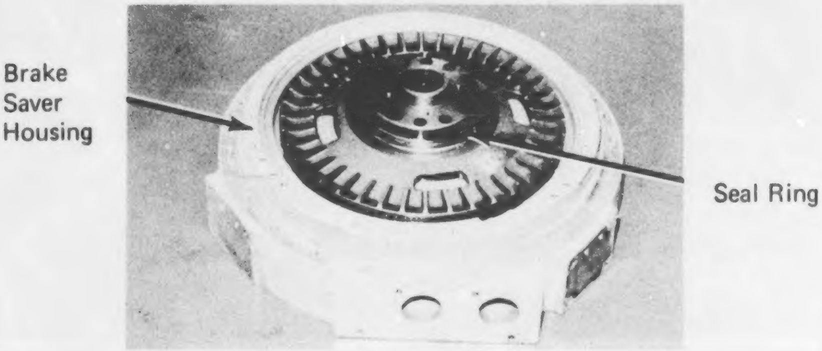
E. Install carrier on each side of rotor and install wear sleeve with the taper edge of sleeve in the "Up" position (Figure 2)

FIGURE 2


Rotor
Sleeve
Carrier

F. Install a seal ring in each of the carriers (Figure 3)

FIGURE 3

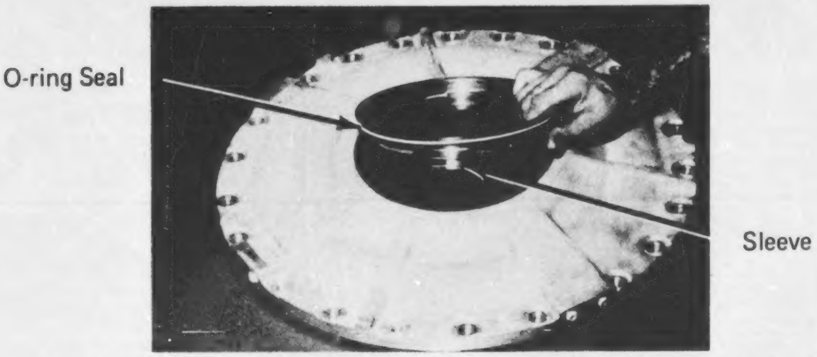

Brake Saver Housing
Seal Ring

G. Install the rotor assembly in Brakesaver housing (Figure 3)

JOB SHEET #4

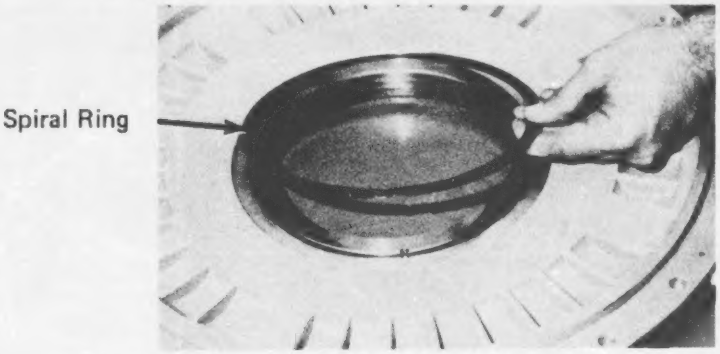
H. Install O-ring seal on the sleeve, and install sleeve in the stator; make alignment of the notch in the sleeve with the dowel in the stator (Figure 4)

FIGURE 4


O-ring Seal
Sleeve

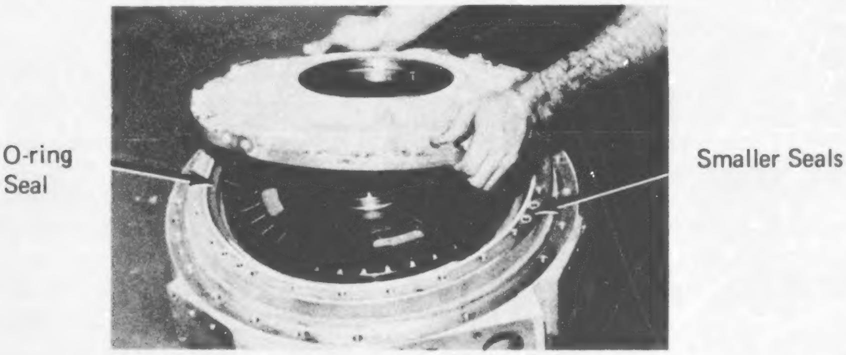
I. Turn the stator over and install spiral ring that holds the sleeve in the stator (Figure 5)

FIGURE 5


Spiral Ring

J. Install O-ring seal and six smaller seals for the oil holes on the housing (Figure 6)

FIGURE 6


O-ring Seal
Smaller Seals

JOB SHEET #4

K. Put the stator in the correct location on the housing with respect to the identification put on at removal; make sure the oil holes in the stator and the housing are in alignment

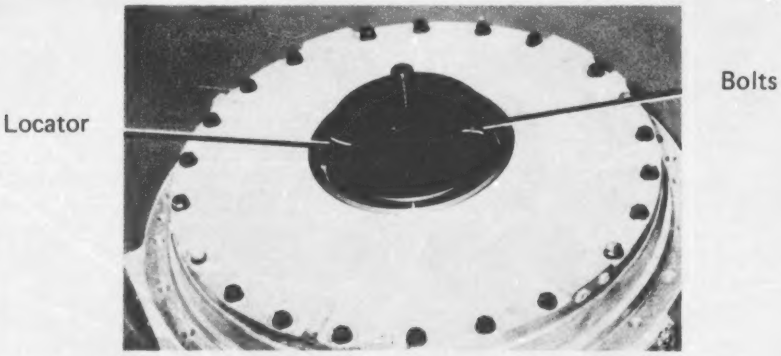
L. Install the bolts that hold stator to the housing and tighten to specification torque

M. Follow the steps below when installing the lip type seals

1. Put clean engine oil on the lip of the seals
2. Put the pilot inside the seal and install pilot and seal with the inside taper of the pilot against the wear sleeve

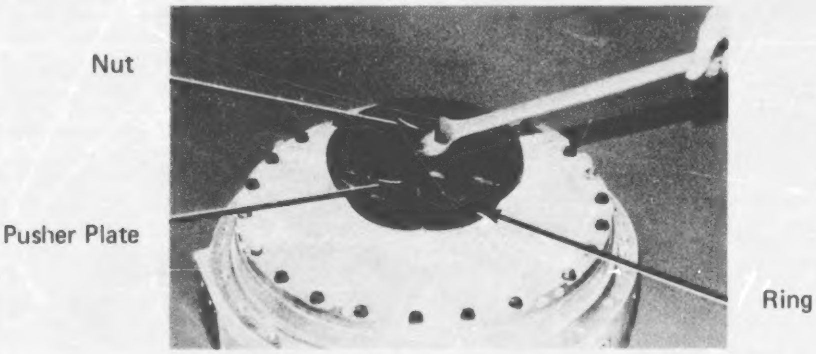
   (NOTE: The lip of the seal must be toward the rotor.)
3. Install locator and bolts on the rotor (Figure 7)

FIGURE 7



4. Put ring over the locator and plate on the ring (Figure 8)

FIGURE 8

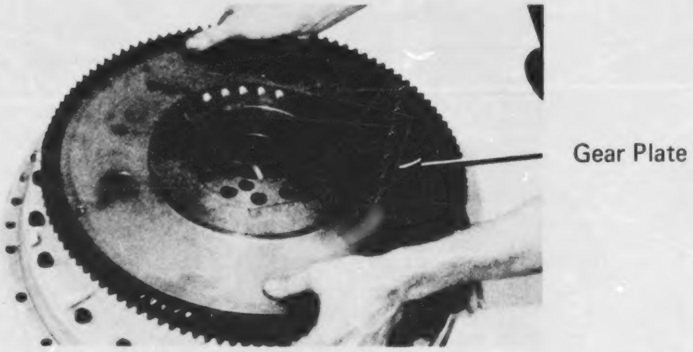


5. Tighten nut on the locator until tooling is at bottom (Figure 8)

JOB SHEET #4

N. Install gear plate and the bolts that hold it on the rotor (Figure 9)

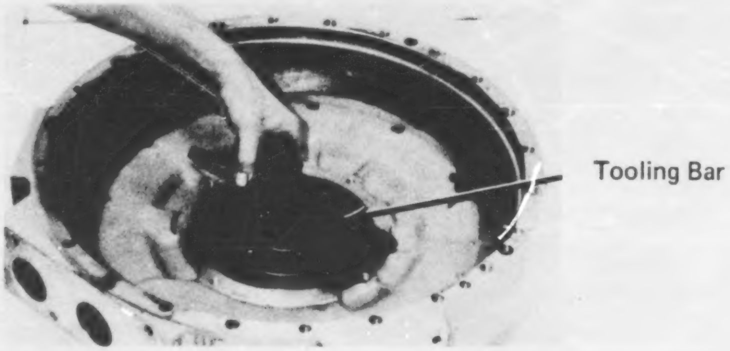
FIGURE 9



O. Turn the housing over carefully and do "Step M" again to install the other lip type seal on the rotor

P. Install tooling bar to the rotor and the housing (Figure 10)

FIGURE 10



(NOTE: Tooling bar will prevent damage to the rotor seals and rings at installation.)

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #5--INSTALL A BRAKESAVER

I. Tools and materials

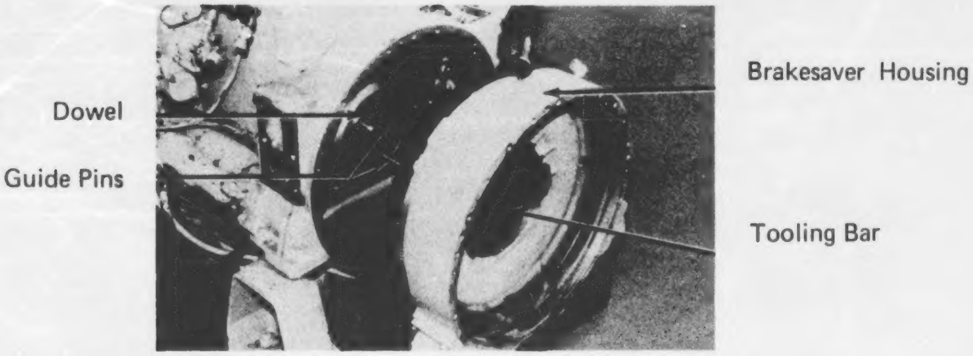
- A. Basic hand tools
- B. Appropriate service manual
- C. Shop towels
- D. Safety glasses
- E. Brakesaver assembly

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Install tooling on the Brakesaver housing and rotor (Figure 1)

FIGURE 1



(NOTE: Tooling plate holds the Brakesaver housing and rotor assembly together at installation, and this prevents damage to the rotor rings and seals.)

B. Install eye bolt in the top of the Brakesaver housing and fasten a hoist (Figure 1)

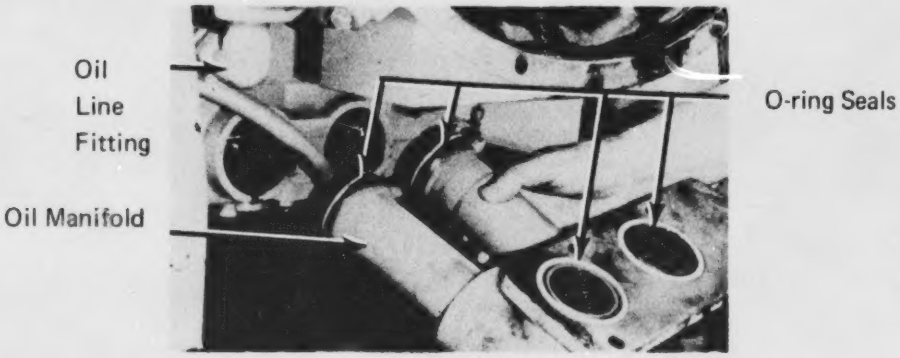
JOB SHEET #5

C. Install two guide pins in the crankshaft, as shown, and make sure dowel is in alignment with the dowel hole in the rotor assembly; put Brakesaver housing in position in the flywheel housing (Figure 1)

D. Install the bolts that hold Brakesaver housing to the flywheel housing and remove the tooling bar and guide pins

E. Connect the oil line to fitting (Figure 2)

FIGURE 2

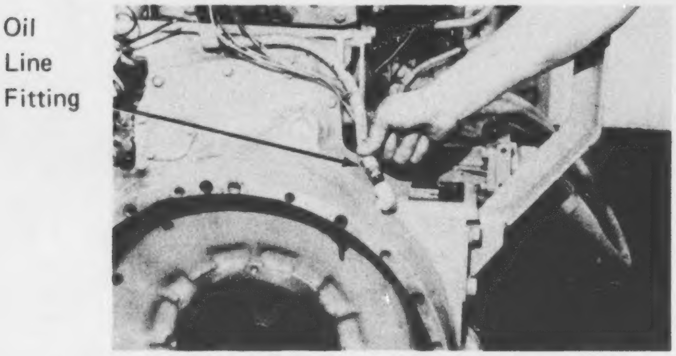


F. Inspect the O-ring seals for damage and replace, if needed; install O-rings and put clean oil on the O-ring seals (Figure 2)

G. Install manifold into the Brakesaver control valve and install the bolts that hold the manifold to the Brakesaver housing (Figure 2)

H. Connect Brakesaver lubrication oil line to the fitting in the Brakesaver housing (Figure 3)

FIGURE 3



I. Install flywheel to Brakesaver

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #6--INSTALL A JACOBS ENGINE BRAKE ON A MACK DIESEL

I. Tools and materials

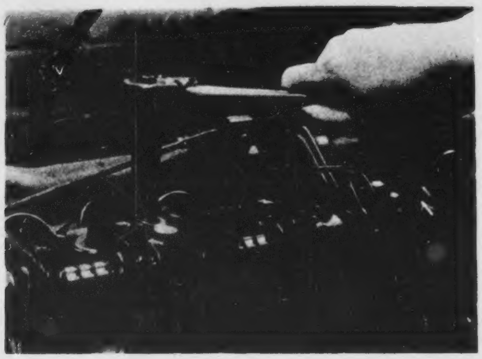
- A. Basic hand tools
- B. Mack service manual
- C. Clean shop towels
- D. Torque wrench
- E. Feeler gauge
- F. Safety glasses

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Remove rocker arm shaft assemblies from engine and note the location of all exhaust valve rocker levers (Figure 1)

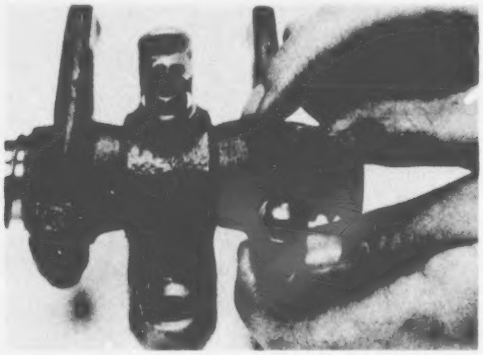
FIGURE 1



JOB SHEET #6

B. Replace exhaust valve rocker arm adjusting screws with new adjusting screws from kit (Figure 2)

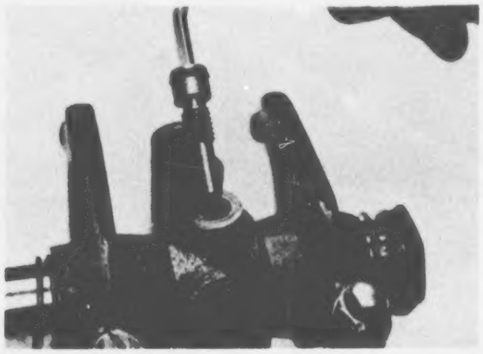
FIGURE 2



(CAUTION: To provide proper clearance between rocker arm and underside of brake housing, gauge rocker arm and grind if necessary in area shown in figure 3.)

C. Replace rocker arm shaft set screws in top face of rocker pedestals over cylinders #1 and #4 with Jacobs oil supply screws (Figure 3)

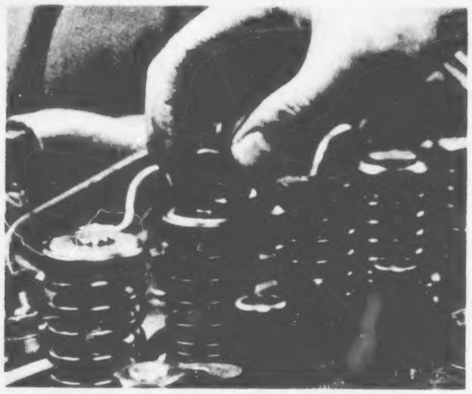
FIGURE 3



JOB SHEET #6

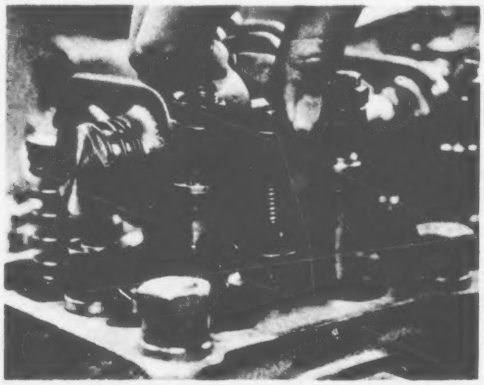
D. Replace exhaust valve stem caps over all exhaust valve stems (Figure 4)

FIGURE 4



E. Replace rocker assemblies and new O-rings, if necessary, under pedestals; start, but do not tighten, the six short holddown cap screws to locate the rocker shaft brackets, making sure push rods are in their respective sockets (Figure 5)

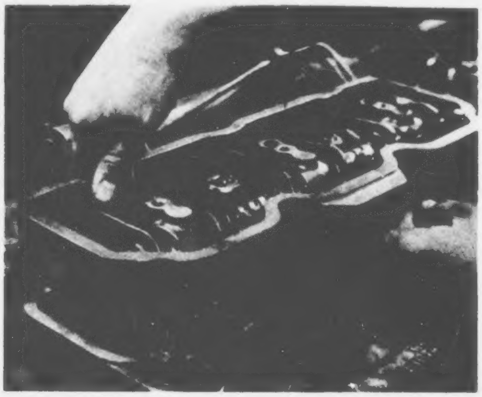
FIGURE 5



JOB SHEET #6

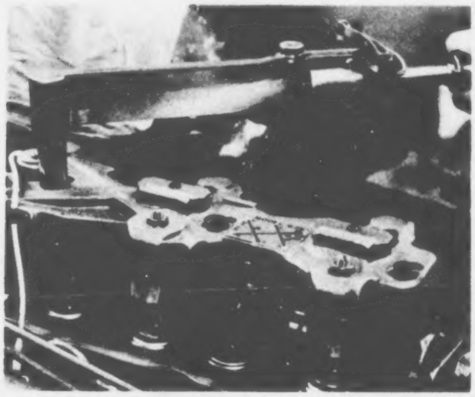
F. Install engine brake housing (Figure 6)

FIGURE 6



G. Insert six long holddown cap screws connecting brake housing and rocker arm shaft assemblies to cylinder heads, and torque to specification (Figure 7)

FIGURE 7



H. Before starting engine, adjust intake and exhaust valves as instructed by *Mack Operation and Maintenance Manual* for cold static clearance

I. Back off all engine brake slave piston adjusting screws 1/2" above top face of housing

J. Proceed to run engine until normal hot idle temperature for valve adjustment is reached

K. Shut engine down and make hot valve adjustment

(NOTE: Valve adjustment should **NOT** be attempted with engine running.)

ENGINE BRAKES AND RETARDERS
UNIT V

JOB SHEET #7--ADJUST SLAVE PISTON ON A JACOBS ENGINE BRAKE ON A MACK DIESEL

I. Tools and materials

   A. Basic hand tools

   B. Mack service manual

   C. Clean shop towels

   D. Torque wrench

   E. Feeler gauge

   F. Safety glasses

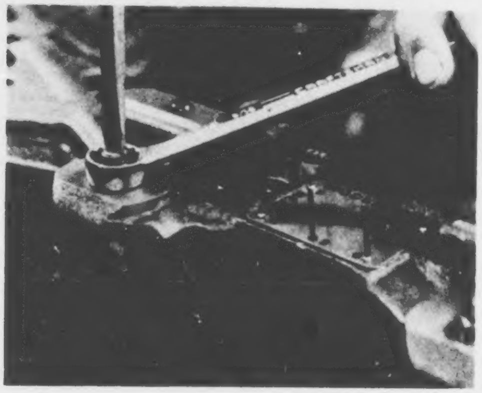
II. Procedure

(CAUTION: To insure maximum brake operating efficiency and to prevent engine damage by piston to valve contact, the following instructions must be followed carefully. Follow all shop safety procedures.)

   A. Close exhaust valves fully and turn in slave piston adjusting screw until zero clearance is established between slave piston feet and exhaust valve stem cap

   B. Back out adjusting screw 3/4 turn to establish proper operating clearance (Figure 1)

FIGURE 1



(CAUTION: Do not turn adjusting screw in far enough to open exhaust valve.)

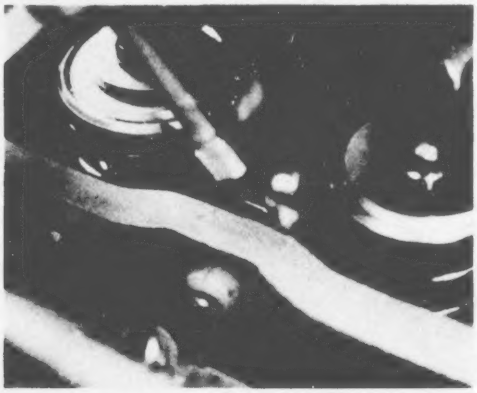
JOB SHEET #7

C. Hold adjusting screw with screwdriver and tighten jam nut

(NOTE: The above adjustment may be made with the engine hot or cold, but it must be shut down.)

D. Connect solenoid valve leads to terminals on inside of cylinder head cover spacers (Figure 2)

FIGURE 2



ENGINE BRAKES AND RETARDERS
UNIT V

NAME______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Uses a valve in the exhaust which keeps the exhaust gases backed up in the exhaust manifold

_____b. Stops air pulsations

_____c. Operates exhaust valves

_____d. Disengages compression brake

_____e. Supplies high pressure oil to slave piston

_____f. Device used to convert the engine into a compressor or air pump, thus effectively braking the vehicle

_____g. Device used to convert the engine into a compressor or air pump, thus effectively slowing the engine down

1. Air suppressor
2. Clutch switch
3. Engine retarder
4. Exhaust brake
5. Slave piston
6. Engine brake
7. Master piston

2. Select true statements concerning Jacobs engine brake operation by placing an "X" in the appropriate blanks.

_____a. Driver operates an electrical switch

_____b. A solenoid valve permits lubricating oil to flow under pressure through the slave piston control valve to both the master piston and slave piston

_____c. Oil pressure causes the master slave piston to move down, coming to rest on the injector rocker arm adjusting screw

_____d. The injector rocker arm adjusting screw begins upward travel forcing the slave piston upward and creating a high pressue oil flow to the master piston

_____e. The ball check valve in the control valve imprisons high pressure oil in the master piston only

_____f. The slave piston under the influence of high pressure oil flow moves down, momentarily opening the exhaust valve, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust mainfold

_____g. Compressed air escapes into the atmosphere, completing a compression braking cycle; after piston starts down on power stroke and all valves are closed; this creates a vacuum

3. Complete the following list of troubleshooting procedures for the Jacobs engine brake.

   a. Engine fails to start--Solenoid valves stuck in the open position

   b. Drop in engine lube oil pressure

      1. Oil inlet supply seal ____

      2. Upper solenoid valve seal missing or damaged

      3. Fuel line leakage

   c. One or two cylinders fail to brake

      1. Slave piston control valve stuck in "Off" position

      2. Slave piston control valve failure

      3. Slave piston adjustment incorrect

      4. Engine brake housing oil connector or seals leaking

   d. Solenoids won't control brake operation--____________________________

      ________________________ missing or damaged

   e. Solenoids will not energize

      1. Blown fuse

      2. Automatic switches ____

      3. Incorrect electrical power source

   f. Engine brake slow to operate

      1. Lube oil cold and/or too thick

      2. Lower solenoid valve seal missing or damaged

      3. Solenoid valve filter screen clogged

      4. Control valves binding in housing

      5. Switch operation sluggish

      6. Incorrect adjustments

   g. One or more cylinders fail to stop braking or engine stalls

      1. One or more slave piston control valves stuck in ____________________

      2. Solenoid valve sticking in "On" position

      3. Center solenoid valve seal missing or damaged

   4. Solenoid valve exhaust plugged

   5. Switch stu[illegible] "On" position or misadjusted

   6. Buffer switch set too tight

4. Complete the following list of advantages of the Jacobs engine brake.

   a. Brake lining and brake drum life is ______________________ __that obtained without the Jacobs engine brake

   b. The ability of the brake to maintain engine operating temperatures on down hill grades and the possibility that the frequency of valve setting can be reduced, all lend a hand in __________________________ of diesel vehicle operation

   c. A minimum amount of labor is required for installation with very little service needed

   d. The elimination of continual braking with vehicle service brakes and the resulting reduction of heat add considerably to ____________________________________

   e. ___________________________ can be obtained through use of the engine brake, providing valuable extra hours

5. Select true statements concerning the operation of the Brakesaver by placing an "X" in the appropriate blanks.

   _____a. The rotor is fastened to and turns with the engine crankshaft; the rotor has pockets on the outer circumference of both sides and four holes to permit equal flow to both sides of the rotor

   _____b. The housing and stator are fastened to the crankshaft and cannot turn, and both have pockets on their inside surfaces in alignment with the pockets in the motor

   _____c. The rotor turns in the compartment made by the stator and the Brakesaver housing

   _____d. When housing is in operation, engine oil comes in near center from a passage at bottom of the housing

   _____e. The rotor turns with crankshaft and throws this oil outward; the shape of the rotor pockets send it to the pockets of the stator and housing

   _____f. As the rotor turns and oil flows through the Brakesaver compartment, it takes the shape of a triangle

   _____g. The oil flow is constantly cut by the vanes of the rotor; this cutting action gives resistance to the oil

   _____h. When Brakesaver is in operation, the level of braking can be controlled by the inlet oil pressure, since the amount of oil is cut by the rotor vanes

   _____i. When Brakesaver is not in operation, the inlet passage to the rotor is open by the control valve and there is oil in the Brakesaver compartment

6. Demonstrate the ability to:

    a. Adjust a Jacobs engine brake on a Detroit diesel.

    b. Remove Brakesaver on a Caterpillar diesel engine.

    c. Disassemble a Brakesaver.

    d. Assemble a Brakesaver.

    e. Install a Brakesaver.

    f. Install a Jacobs engine brake on a Mack diesel.

    g. Adjust slave piston on a Jacobs engine brake on a Mack diesel.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ENGINE BRAKES AND RETARDERS
UNIT V

ANSWERS TO TEST

1. a. 4
    b. 1
    c. 5
    d. 2
    e. 7
    f. 6
    g. 3

2. a, b, c, f, g,

3. b. Missing or damaged
    d. Center solenoid valve seal
    e. Fail to close
    g. "On" position

4. a. Extended up to five times
    b. Lowering overall maintenance costs
    d. Tire life and wear
    e. Shorter round trip schedules

5. a, c, d, e, g, h

6. Performance skills evaluated to the satisfaction of the instructor

OPERATION AND MAINTENANCE
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the major duties of an engine operator and list causes of engine knock and an overheated engine. The student should also be able to demonstrate the ability to complete a preliminary checklist before starting engine, during normal engine operation, and before stopping engine. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with operation and maintenance.
2. List four major duties of an engine operator.
3. List inspections to include in a checklist before starting a diesel engine.
4. List inspections to include in a checklist during normal operation.
5. List factors to include in the procedure for stopping a diesel engine.
6. Name two performance records that should be maintained.
7. Match the causes of engines being hard to start or will not start with the corrective actions.
8. Match the causes of an engine failing to come up to speed with the corrective actions.
9. Match the causes of an engine misfiring with the corrective actions.
10. List causes of engine knock.
11. List causes of an overheated engine.
12. List four causes of smokey exhaust.
13. Demonstrate the ability to:
    a. Complete a preliminary checklist before starting engine.
    b. Complete a checklist during normal engine operation.
    c. Complete a checklist before stopping engine.

OPERATION AND MAINTENANCE
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Discuss unit and specific objectives.

IV. Discuss information sheet.

V. Demonstrate and discuss the procedures outlined in the job sheets.

VI. Show film on engine shut-down devices.

VII. Display different engine dipsticks.

VIII. Have student make a list of items to check other than engine.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Job sheets
    1. Job Sheet #1--Complete a Preliminary Checklist Before Starting Engine
    2. Job Sheet #2--Complete a Checklist During Normal Engine Operation
    3. Job Sheet #3--Complete a Checklist Before Stopping Engine
- D. Test
- E. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. Chicago: American Technical Society, 1974.

B. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

OPERATION AND MAINTENANCE
UNIT I

INFORMATION SHEET

I. Terms and definitions

- A. Symptom--Subjective evidence of mechanical trouble
- B. Log--Form for keeping engine operating and accountability records
- C. Checklist--Series of inspection points for determining if maintenance or servicing is needed

II. Major duties of an engine operator

- A. Starting engine
- B. Normal running of engine
- C. Stopping engine
- D. Record maintenance

III. Inspections before starting engine

- A. Cooling system
- B. Lubricating system
- C. Fuel system
- D. Starting system
    - 1. Air supply
    - 2. Fuel supply
    - 3. Compression

(NOTE: Immediately after starting, check the lubricating oil pressure, cooling water flow, and fuel supply. Watch entire engine to see if all parts function properly. Run at light load, if possible, until it reaches operating temperature.)

INFORMATION SHEET

IV. Inspections during normal operation

- A. Inspect engine frequently
- B. Watch loading
- C. Regulate jacket water temperature (if used)
- D. Keep lubrication system clean
- E. Check combustion conditions

  (NOTE: Do this on larger engines by taking firing pressure readings through use of indicator cards or pyrometer.)

- F. Listen to the engine

V. Stopping procedure

- A. Make sure starting equipment is fully charged
- B. Check to see that all pressures and temperatures are normal
- C. Take load off engine gradually
- D. Let engine idle until temperature falls
- E. Shut off fuel injection

  (NOTE: If independent water pump or oil pump are used keep in circulation for about 15 minutes.)

VI. Performance records

- A. Operating records

  (NOTE: Typical record form or log should include cooling water and exhaust temperatures, turbocharger pressure, lube-oil pressure, and temperature, electrical, and load date.)

- B. Accounting records

  (NOTE: Typical record form or log should include what the plant produces in terms of kilowatt-hours, water pumped, and ton-miles pulled, and what the plant used in terms of fuel, lube oil, operating labor, supplies, parts, and repair labor.)

INFORMATION SHEET

VII. Causes of engines being hard to start or will not start and corrective actions

- A. Not enough fuel--Check fuel tanks, be sure all valves are open, check transfer pump, clean air filters
- B. Air in fuel line-- Prime and vent pump and piping
- C. Water or dirt in fuel--Drain fuel system and clean tank
- D. Starting valves out of order (if used)--Make sure starting valve is not stuck open or leaking
- E. Low compression--Check for improper valve seating, stuck piston rings, or cylinder head, or valve cage gaskets leaking
- F. Cranking speed too low--Charge or replace battery, service starter
- G. Fuel injection improperly timed--Time injection to manufacturer's specifications

VIII. Causes of an engine failing to come up to speed and corrective actions

- A. Not enough fuel--Adjust governor or throttle controls; check for air or water in fuel
- B. Fuel nozzles dirty or clogged--Clean or replace nozzles
- C. Injection pump valves leak--Regrind or replace valve and seat assemblies
- D. Low compression--Check for improper inlet or exhaust valve seating, cylinder head or valve cage gaskets leaking, or compression release not in position
- E. Engine overloaded--If electrical load, open switches; if mechanical load, open (dump) clutch
- F. Too much friction--Eliminate cause of excess friction

IX. Causes of an engine misfiring and corrective actions

- A. Water or dirt in fuel--Drain and refill with clean fuel
- B. Gasoline in diesel fuel--Drain and refill with proper fuel
- C. Air in fuel system--Bleed the system

INFORMATION SHEET

D. Poor nozzle operation--Clean and check nozzle spray pattern

E. Faulty injection pump--Check and calibrate the fuel injection pump

F. Nozzles not seated properly--Reposition nozzles and tighten retaining screws to specified torque

X. Causes of engine knock

A. Injector valves sticking; broken valve spring

B. Fuel timing wrong

C. Inlet or exhaust valve sticking

D. Poor quality fuel; dirt or water in fuel

E. Worn bearings; excessive valve tappet clearance

(NOTE: Pounding may be caused by loose crankpin, excessive clearance in wrist pin; excessive clearance, liner-to-piston.)

XI. Causes of an overheated engine

A. Overload

B. Poor cooling

C. Late combustion

D. Lubrication inadequate

E. Hot bearings

XII. Causes of smokey exhaust

A. Engine overloaded (fuel to air ratio)

B. Poor combustion

C. Excessive lubrication

D. Clogged air cleaners

OPERATION AND MAINTENANCE
UNIT I

JOB SHEET #1--COMPLETE A PRELIMINARY CHECKLIST BEFORE STARTING ENGINE

I. Tools and materials

- A. Basic shop tools
- B. Lubricant (if needed)
- C. Clean shop towels
- D. Water (if needed)
- E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: In the spaces to the right of each step, indicate if you found components "satisfactory" or "unsatisfactory" by placing an "X" in the appropriate box.)

A. Complete the following checklist before starting engine

	Satisfactory	Unsatisfactory
1. Check air intake and exhaust system		
a. Inspect pre-cleaner	☐	☐
b. Remove and inspect air cleaner	☐	☐
c. Swab out inlet pipe in air cleaner body	☐	☐
d. Inspect exhaust system and muffler	☐	☐
e. Check crankcase ventilating system for restrictions	☐	☐
2. Check basic engine for leakage at cylinder head gasket	☐	☐

JOB SHEET #1

	Satisfactory	Unsatisfactory
3. Check fuel system		
a. Check fuel lines for leaks or restrictions	☐	☐
b. Inspect fuel pump sediment bowl	☐	☐
c. Check diesel injection pump	☐	☐
4. Check condition of crankcase oil in lubrication system	☐	☐
5. Check cooling system		
a. Check water pump for leaks and excessive shaft end play	☐	☐
b. Inspect radiator hoses	☐	☐
c. Test radiator for leaks	☐	☐
d. Check condition of fan belt	☐	☐
6. Check electrical system		
a. Check battery		
(1) Inspect battery, cable, terminals, and battery box	☐	☐
(2) Inspect battery cables and battery hold-down	☐	☐
(3) Check specific gravity of electrolyte and add water to proper level	☐	☐
b. Check belt tension on generator or alternator	☐	☐

B. Correct items as necessary

OPERATION AND MAINTENANCE
UNIT I

JOB SHEET #2--COMPLETE A CHECKLIST DURING NORMAL ENGINE OPERATION

I. Tools and materials

- A. Basic shop tools
- B. Lubricant (if needed)
- C. Clean shop towels
- D. Water (if needed)
- E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: In the spaces to the right of each step, indicate if you found components "satisfactory" or "unsatisfactory" by placing an "X" in the appropriate box.)

A. Complete the following checklist during normal engine operation

	Satisfactory	Unsatisfactory
1. Check air intake and exhaust system		
a. Inspect exhaust system and muffler	☐	☐
b. Check crankcase ventilating system for restrictions	☐	☐
2. Recheck basic engine		
a. Check air intake for restrictions	☐	☐
b. Check radiator for air bubbles or oil indicating compression or oil leaks	☐	☐
c. Recheck for leakage at cylinder head gasket	☐	☐

JOB SHEET #2

	Satisfactory	Unsatisfactory
3. Check lubrication system		
a. Check operation of pressure gauge or light	☐	☐
b. Check engine oil pressure	☐	☐
4. Check cooling system by testing radiator for leaks	☐	☐

B. Correct items as necessary

OPERATION AND MAINTENANCE
UNIT I

JOB SHEET #3--COMPLETE A CHECKLIST BEFORE STOPPING ENGINE

I. Tools and materials

A. Basic shop tools

B. Lubricant (if needed)

C. Clean shop towels

D. Water (if needed)

E. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: In the spaces to the right of each step, indicate if you found components "satisfactory" or "unsatisfactory" by placing an "X" in the appropriate box.)

	Satisfactory	Unsatisfactory
A. Complete the following checklist before stopping engine (external)		
1. Check cooling system for leaks	☐	☐
2. Check lubrication system for leaks	☐	☐
3. Check fuel system for leaks	☐	☐
4. Check air system for leaks	☐	☐
5. Check hydraulic system for leaks	☐	☐
B. Complete the following checklist before stopping engine (gauges)		
1. Make sure starting equipment is fully charged	☐	☐
2. Check to see that all pressures and temperatures are normal	☐	☐
3. Take load of engine gradually	☐	☐
4. Let engine idle until temperature falls	☐	☐
5. Shut off fuel injection	☐	☐

OPERATION AND MAINTENANCE
UNIT I

NAME ______________________

TEST

1. Define terms associated with operation maintenance.
    a. Symptom-- ______________________
    b. Log-- ______________________
    c. Checklist-- ______________________
2. List four major duties of an engine operator.
    a. ______________________
    b. ______________________
    c. ______________________
    d. ______________________
3. List three inspections to include in a checklist before starting a diesel engine.
    a. ______________________
    b. ______________________
    c. ______________________
4. List four inspections to include in a checklist during normal operation.
    a. ______________________
    b. ______________________
    c. ______________________
    d. ______________________
5. List four factors to include in the procedure for stopping a diesel engine.
    a. ______________________
    b. ______________________
    c. ______________________
    d. ______________________

6. Name two performance records that should be maintained.

a. ____

b. ____

7. Match the causes of engines being hard to start or will not start on the right with the corrective actions on the left.

______ a. Check fuel tanks, be sure all valves are open, check transfer pump, clean air filters

______ b. Prime and vent pump and piping

______ c. Drain fuel system and clean tank

______ d. Make sure starting valve is not stuck open or leaking

______ e. Check for improper valve seating, stuck piston rings, or cylinder head, or valve cage gaskets leaking

______ f. Charge or replace battery, service starter

______ g. Time injection to manufacturer's specifications

1. Low compression
2. Starting valves out of order (if used)
3. Fuel injection improperly timed
4. Cranking speed too low
5. Water or dirt in fuel
6. Not enough fuel
7. Air in fuel line

8. Match the causes of an engine failing to come up to speed on the right with the corrective actions on the left.

______ a. Adjust governor or throttle controls; check for air or water in fuel

______ b. Clean or replace nozzles

______ c. Regrind or replace valve and seat assemblies

______ d. Check for improper inlet or exhaust valve seating, cylinder head or valve cage gaskets leaking, or compression release not in position

______ e. If electrical load, open switches; if mechanical load, open (dump) clutch

______ f. Eliminate cause of excess friction

1. Low compression
2. Not enough fuel
3. Fuel nozzles dirty or clogged
4. Injection pump valves leak
5. Too much friction
6. Engine overloaded

9. Match the causes of an engine misfiring on the right with the corrective actions on the left.

______ a. Drain and refill with clean fuel

______ b. Drain and refill with proper fuel

______ c. Bleed the system

______ d. Clean and check nozzle spray pattern

______ e. Check and calibrate the fuel injection pump

______ f. Reposition nozzles and tighten retaining screws to specified torque

1. Faulty injection pump
2. Air in fuel system
3. Nozzles not seated properly
4. Water or dirt in fuel
5. Poor nozzle operation
6. Gasoline in diesel fuel

10. List four causes of engine knock.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

11. List four causes of an overheated engine.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

12. List four causes of smokey exhaust.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

13. Demonstrate the ability to:

    a. Complete a preliminary checklist before starting engine.

    b. Complete a checklist during normal engine operation.

    c. Complete a checklist before stopping engine.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

OPERATION AND MAINTENANCE
UNIT I

ANSWERS TO TEST

1. a. Symptom--Subjective evidence of mechanical trouble
   b. Log--Form for keeping engine operating and accountability records
   c. Checklist-Series of inspection points for determining if maintenance or servicing is needed

2. a. Starting engine
   b. Normal running of engine
   c. Stopping engine
   d. Record maintenance

3. Any three of the following:

   a. Cooling system
   b. Lubricating system
   c. Fuel system
   d. Starting system
      1. Air supply
      2. Fuel supply
      3. Compression

4. Any four of the following:

   a. Inspect engine frequently
   b. Watch loading
   c. Regulate jacket water temperature (if used)
   d. Keep lubrication system clean
   e. Check combustion conditions
   f. Listen to the engine

5. Any four of the following:

   a. Make sure starting equipment is fully charged
   b. Check to see that all pressures and temperatures are normal
   c. Take load off engine gradually
   d. Let engine idle until temperature falls
   e. Shut off fuel injection

6. a. Operating records
   b. Accounting records

7. a. 6
   b. 7
   c. 5
   d. 2
   e. 1
   f. 4
   g. 3

8. a. 2 d. 1
b. 3 e. 6
c. 4 f. 5

9. a. 4 d. 5
b. 6 e. 1
c. 2 f. 3

10. Any four of the following:

    a. Injector valves sticking; broken valve spring
    b. Fuel timing wrong
    c. Inlet or exhaust valve sticking
    d. Poor quality fuel; dirt or water in fuel
    e. Worn bearings; excessive valve tappet clearance

11. Any four of the following:

    a. Overload
    b. Poor cooling
    c. Late combustion
    d. Lubrication inadequate
    e. Hot bearings

12. a. Engine overloaded (fuel to air ratio)
    b. Poor combustion
    c. Excessive lubrication
    d. Clogged air cleaners

13. Performance skills evaluated to the satisfaction of the instructor

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to list basic steps to follow in diagnosing and testing an engine. The student should also be able to demonstrate the ability to load test an engine with a dynamometer and test engine cylinder compression. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

1. Match terms associated with diagnosis and testing of engines with the correct definitions.
2. Arrange in order the steps in diagnosing and testing an engine.
3. List four major checkpoints when inspecting a diesel engine.
4. Complete a list of major checks to make when operating an engine.
5. List tests that are made with a dynamometer.
6. Name three factors necessary for an engine to produce horsepower.
7. Select the possible causes of a diesel engine being hard to start or not starting.
8. Select the possible causes of a diesel engine starting but not running.
9. Complete a list of items which would cause a diesel engine to misfire.
10. Select the items which would cause a diesel engine to knock.
11. Select the items which would cause a diesel engine to overheat.
12. Circle the items which would cause a diesel engine to have lack of power.
13. Select the items which would cause a diesel engine to use too much oil.
14. Name causes of high oil pressure.
15. List causes of low oil pressure.
16. Complete a diesel troubleshooting guide.

17. Demonstrate the ability to:
    a. Load test an engine with a dynamometer.
    b. Test engine cylinder compression.
    c. Check air intake system for restrictions.
    d. Check crankcase pressure, exhaust back pressure, and air box pressure.

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Discuss unit and specific objectives.

IV. Discuss information and assignment sheets.

V. Demonstrate and discuss the procedures outlined in the job sheets.

VI. Explain how to properly use and read a mercury and a water-filled manometer.

VII. Show students film on dust conditions.

VIII. Have students make a list of torque loss items.

IX. Have students draw a compression gauge.

X. Take field trip to a service center that has a dynamometer.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Assignment Sheet #1--Complete a Diesel Troubleshooting Guide
- D. Answers to assignment sheet
- E. Job sheets
    1. Job Sheet #1--Load Test an Engine with a Dynamometer
    2. Job Sheet #2--Test Engine Cylinder Compression
    3. Job Sheet #3--Check Air Intake System for Restrictions
    4. Job Sheet #4--Check Crankcase Pressure, Exhaust Back Pressure, and Air Box Pressure
- F. Test
- G. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair*. South Holland, Illinois: Goodheart-Willcox Company, 1980.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. Chicago: American Technical Society, 1974.

C. *Fundamentals of Service: Engines*. 5th ed. Moline, Illinois: Deere and Company, 1980.

D. *Service Manual, Detroit Diesel Engines*. Detroit, Michigan: Detroit Diesel Allison, 1975.

E. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, 1974.

F. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc. 1982.

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Diagnosis--In engine service, the use of instruments to troubleshoot the engine parts to locate the cause of failure

B. Dynamometer-Instrument for measuring the power output of an engine by applying a load to the engine, thereby testing the horsepower and torque

C. Vacuum gauge--Instrument used to check the air intake system of an engine

(NOTE: A vacuum gauge measures pressure of liquids and gases.)

D. Manometer--Instrument using mercury or water in a U-tube, indicating positive or negative (vacuum) pressure by the difference in height of the two columns

E. Tachometer--Device measuring speed of rotation

F. Pyrometer--Instrument for measuring temperatures beyond the range of a mercurial thermometer

II. Steps in diagnosing and testing an engine

A. Ask the operator

(NOTE: Ask operator what warning signs preceeded the trouble; what previous work has been done on the engine; and if similar trouble has occurred before.)

B. Know the system

(NOTE: Study technical manuals, how engine works, knowledge of three basic needs: fuel-air mixture, compression, and ignition.)

C. Operate the machine

D. Inspect the machine

(NOTE: Check all fluid levels.)

E. List the possible causes

F. Reach a conclusion

G. Test your conclusion

INFORMATION SHEET

III. Major checkpoints

  A. Water system

  B. Oil system

  C. Fuel system

  D. Electrical system

  (NOTE: Keep a list of all trouble signs noted from above checks.)

IV. Checks when operating an engine

  A. Gauge readings

  B. Unusual sounds (where? at what speed?)

  C. Smells (any signs of unusual exhaust)

  D. Smoke

  E. Controls

  F. Power under load

  G. Idle speed

  H. Battery condition

  I. Alternator or generator output

V. Tests made with a dynamometer

  A. Engine horsepower

  B. Exhaust smoke analysis

  C. Fuel consumption

  D. Crankcase blow-by

  E. Air cleaner restriction

  F. Oil pressure

  G. Clutch operation

INFORMATION SHEET

- H. Exhaust temperature
- I. Air box pressure
- J. Exhaust pressure

VI. Factors necessary to produce horsepower

- A. Fuel-air mixture
- B. Compression
- C. Ignition

VII. Causes of a diesel engine being hard to start or will not start

- A. No fuel or improper fuel
- B. Water or dirt in fuel or dirty filters
- C. Air in fuel system
- D. Low cranking speed
- E. Faulty nozzle operation
- F. Improper timing
- G. Faulty injection pump

VIII. Causes if diesel engine starts but will not run

- A. Dirt in fuel
- B. Air restrictions
- C. Clogged filter

IX. Causes of diesel engine misfiring

- A. Water or dirt in fuel
- B. Gasoline in diesel fuel
- C. Air in fuel system
- D. Faulty nozzle operation
- E. Faulty injection pump

INFORMATION SHEET

   F. Nozzles not seated properly in cylinder head

   G. Low compression

X. Causes of diesel engine knock

   A. Improper injection pump timing

   B. Worn engine bearings or bushings

   C. Excessive crankshaft end play

   D. Loose bearing caps

   E. Foreign material in cylinder

   F. Scored piston

   G. Faulty injection nozzle

   H. Bad fuel

XI. Causes of diesel engine overheating

   A. Defective radiator cap

   B. Radiator fins bent or plugged

   C. Defective thermostat

   D. Insufficient coolant

   E. Loose fan belt

   F. Cooling system limed up

   G. Overloaded engine

   H. Faulty engine timing

   I. Engine low on oil

   J. Wrong type of fuel

   K. Faulty water pump

   L. Faulty shutter operation (if used)

   M. Faulty nozzles

   N. Fan problems

INFORMATION SHEET

XII. Causes of a diesel engine having lack of power

- A. Air cleaner dirty or otherwise obstructed
- B. Restricted air flow in intake system
- C. Restriction in fuel lines or filters
- D. Wrong type of fuel
- E. Valve failure
- F. Incorrect valve tappet clearance
- G. Low engine speed
- H. Crankcase oil too heavy
- I. Low compression
- J. Low operating temperature
- K. Faulty injection pump delivery
- L. Exhaust restriction
- M. Incorrect camshaft timing

XIII. Causes of a diesel engine using too much oil

- A. Crankcase oil too light
- B. Worn pistons and rings
- C. Worn valve guides or stem oil seals
- D. Loose connecting rod bearings
- E. External oil leaks
- F. Oil pressure too high
- G. Engine speed too high
- H. Crankcase ventilator pump not working
- I. Restricted air intake or breather
- J. Excessive oil in rocker arm assembly

INFORMATION SHEET

XIV. Causes of high oil pressure

  A. Stuck relief valve
  B. Defective pressure gauge
  C. Wrong oil pump
  D. Oil to thick

XV. Causes of low oil pressure

  A. Worn bearings
  B. Poor relief valve seating
  C. Too light oil
  D. Worn oil pump
  E. Engine low on oil
  F. Loose connection or leaky seals at oil filter, pump, or cooler
  G. Defective oil pressure gauge
  H. Dilution of oil

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

ASSIGNMENT SHEET #1--COMPLETE A DIESEL TROUBLESHOOTING GUIDE

The following questions provide a guide for beginning analysis of troubleshooting a diesel.

Select the method on the right that would most likely answer the question.

____ 1) Is acceleration normal?

____ 2) How does it start when cold?

____ 3) How does it start when hot?

____ 4) Is there any misfiring?

____ 5) Under what condition does it misfire?

____ 6) Is exhaust normal?

____ 7) Does the engine surge at any speed?

____ 8) Is there any oil leakage?

____ 9) Is there any coolant leakage?

____10) Is there any fuel leakage?

____11) Is there any air leakage from turbocharger or blower?

____12) Does the engine run hot?

____13) When was the last service work performed?

____14) What work was done on the engine?

____15) Under what conditions is the engine operated?

____16) Are any knocks apparent?

____17) Under what conditions are the knocks apparent?

a. Ask operator

b. Visual inspection

c. Operate engine

d. Compression gauge

e. Dynamometer test

f. Pyrometer (if used)

ASSIGNMENT SHEET #1

____18) What is operating temperature of individual cylinder exhaust?

____19) Is exhaust gas analysis normal?

____20) Is there any restriction in air duct? Any leakage?

____21) What is the compression pressure of various cylinders?

____22) Has the brand of fuel been changed recently?

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

ANSWERS TO ASSIGNMENT SHEET

1. a
2. a
3. a
4. a, c
5. a
6. c
7. a, c
8. b
9. b
10. b
11. b
12. c
13. a
14. a
15. a
16. a, c
17. a, c
18. f
19. e
20. b, e
21. d
22. a

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #1--LOAD TEST AN ENGINE WITH A DYNAMOMETER

I. Tools and materials

- A. Basic hand tool set
- B. Live engine
- C. Dynamometer
- D. Engine technical manual
- E. Dynamometer instruction manual
- F. Safety glasses

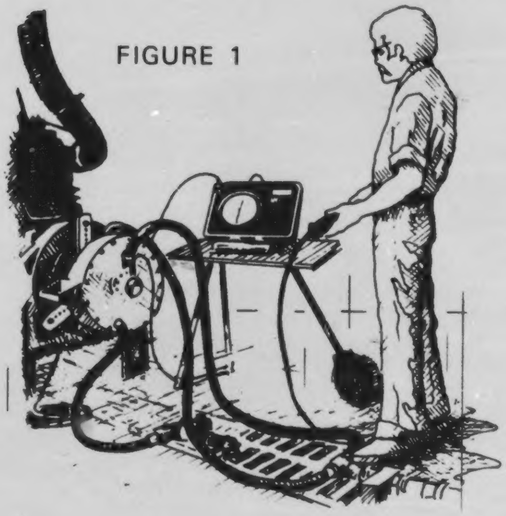
II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Connect the engine to the dynamometer using the manufacturer's instructions (Figure 1)

(CAUTION: Rotating parts are a safety hazard.)

FIGURE 1



Portable Dynamometer

JOB SHEET #1

B. Operate the engine at about one-half load until the coolant and crankcase oil temperatures are up to normal

(NOTE: Warm up will take about 30 minutes but is very important to a good test. Keep close check on engine oil pressure and temperature during test.)

C. Gradually increase the load on the engine until its speed is reduced to rated load speed as given in the engine technical manual

D. Read the horsepower on the dynamometer

(NOTE: On some models a conversion chart or calculator is required to find horsepower. Horsepower can be affected by testing conditions such as altitude, humidity, and temperature.)

E. Compare the horsepower with that given in the engine technical manual

(NOTE: Do not expect engines to always equal these specifications. If the engine rates much lower than normal, this is a signal that service is needed.)

F. While the engine is operating under load, note the outlet of the crankcase ventilating system

G. Remove the crankcase oil filter cap if too much vapor appears

(NOTE: If an excessive amount of vapor or smoke appears here as well as at the vent, there is blow-by in the engine cylinders and they must be reconditioned before the engine will perform at its best.)

H. Check engine technical manual for specified amount of engine vapor flow

(NOTE: Any increase in flow over the specified amount indicates crankcase blow-by.)

I. Recondition the engine for good operation if the blow-by is excessive

(NOTE: Even though the engine develops its rated horsepower using a normal amount of fuel, a tune-up may still improve its efficiency. Consider both hours of operation and the conditions under which the engine has been operated. It is far more economical in the long run to tune the engine before a lack of performance makes it mandatory.)

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #2--TEST ENGINE CYLINDER COMPRESSION

I. Tools and materials

A. Basic hand tool set

B. Compression gauge

C. Live engine

D. Safety glasses

E. Appropriate service manual

II. Procedure

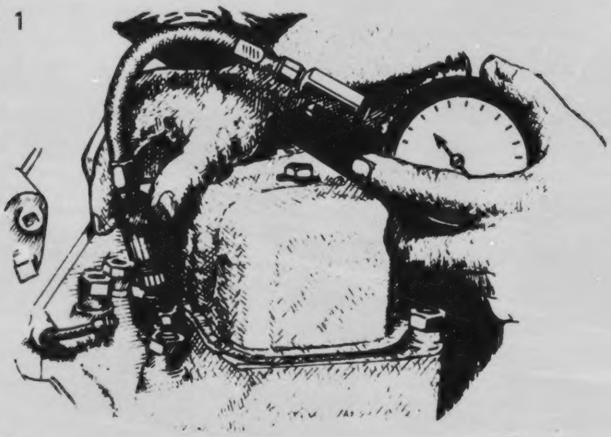
(CAUTION: Follow all shop safety procedures.)

A. Warm up the engine to operating temperature

B. Remove the energy cells injectors, or injection nozzles

C. Connect a pressure gauge to the cylinder port (Figure 1)

FIGURE 1



D. Set the engine speed control to stop position

E. Turn the engine with the starter until the pressure gauge registers no further rise in pressure

(NOTE: It is a good practice to count the number of compression strokes, indicated by movement of the gauge needle, and check each cylinder with the same number of strokes. The engine must be at full cranking speed or as specified in appropriate service manual to get a good reading.)

JOB SHEET #2

F. Check the pressure reading against the engine technical manual

(NOTE: Low pressure indicates leakage through valves, rings, or gaskets. Variations in cylinder pressures of more than 10% usually indicate a need for cylinder reconditioning.)

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #3--CHECK AIR INTAKE SYSTEM FOR RESTRICTIONS

I. Tools and materials

A. Basic hand tool set

B. Live engine

C. Water filled manometer

(NOTE: A vacuum gauge can also be used to make this check.)

D. Pipe tee

E. Shop towels

F. Safety glasses

G. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

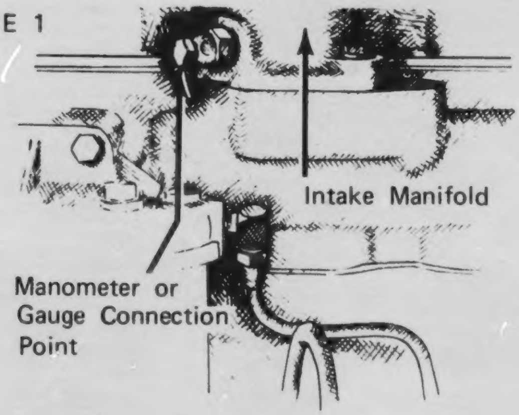
A. Check air intake system for restriction on a naturally aspirated engine

1. Connect manometer to manifold that does not have a restriction indicator

a. Connect manometer to side of intake manifold near middle of manifold (Figure 1)

(NOTE: If a plug is not provided in the manifold intake area, make reading as close to engine as possible in intake piping.)

FIGURE 1



JOB SHEET #3

   b. Start engine and bring to normal operating temperature and governed speed

   c. Check the normal air inlet vacuum at various speeds (no load)

   d. Compare results with the engine technical manual operating specifications

2. Connect manometer to manifold with restriction indicator

   a. Remove the indicator

   b. Install a pipe tee fitting

   c. Reinstall the indicator

   d. Connect the gauge to the tee fitting

   e. Start engine and bring to normal operating temperature and governed speed

   f. Check the normal air inlet vacuum at various speeds (no load)

   g. Compare results with the engine technical manual operating specifications

3. Check the operation of the air restriction indicator, if used

   a. Use a board or metal plate to slowly cover the air intake opening

   b. Note the action of the indicator in relation to the reading on the gauge

   c. Replace indicator if it does not operate properly

B. Check air intake system for restriction on a turbocharged engine

1. Connect manometer to air intake pipe

   (NOTE: Connection should be made about 2" upstream from turbocharger inlet, in a straight section of pipe.)

2. Start engine and bring to normal operating temperature and at governed speed

JOB SHEET #3

3. Measure the restriction when engine is under full load

   (NOTE: On some engines you may remove the air cleaner and ducting and note the gauge readings at various speeds; the difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaning and ducting.)

4. Compare results with the engine technical manual operating specifications

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #4--CHECK CRANKCASE PRESSURE, EXHAUST BACK PRESSURE, AND AIR BOX PRESSURE

I. Tools and materials

A. Basic hand tool set

B. Live engine

C. Water filled manometer

D. Mercury filled manometer

E. 1/8" pipe plug

F. Small tap and die set

G. Shop towels

H. Safety glasses

I. Appropriate service manual

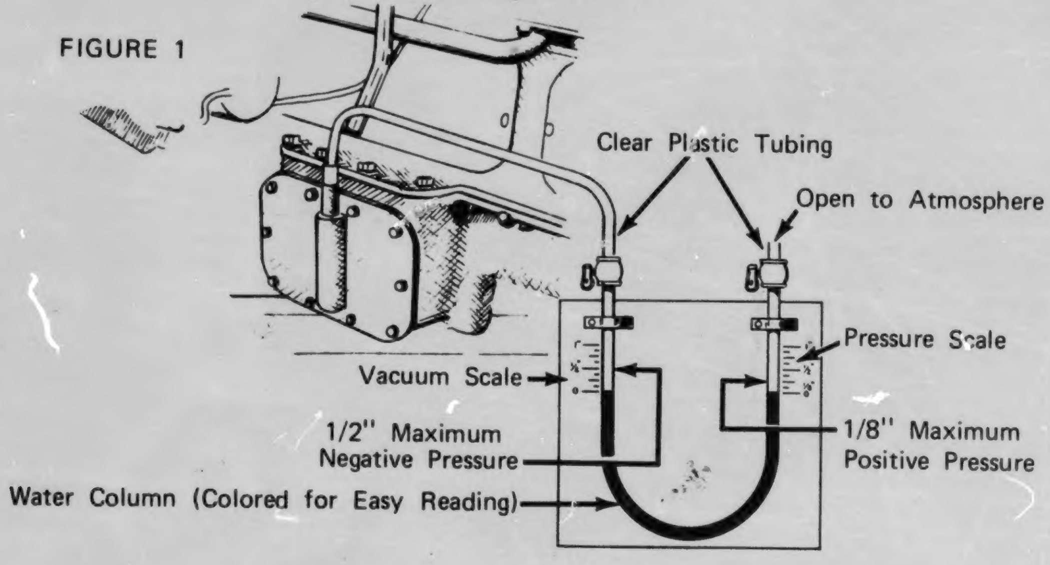
II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Check crankcase pressure

1. Connect water manometer to the oil dipstick opening in the cylinder block (Figure 1)

FIGURE 1


Clear Plastic Tubing
Open to Atmosphere
Pressure Scale
Vacuum Scale
1/2" Maximum Negative Pressure
1/8" Maximum Positive Pressure
Water Column (Colored for Easy Reading)

JOB SHEET #4

2. Operate the engine at manufacturer's rated load speeds and note the readings obtained

3. Compare the readings to specifications in the engine technical manual operating conditions

B. Check exhaust back pressure

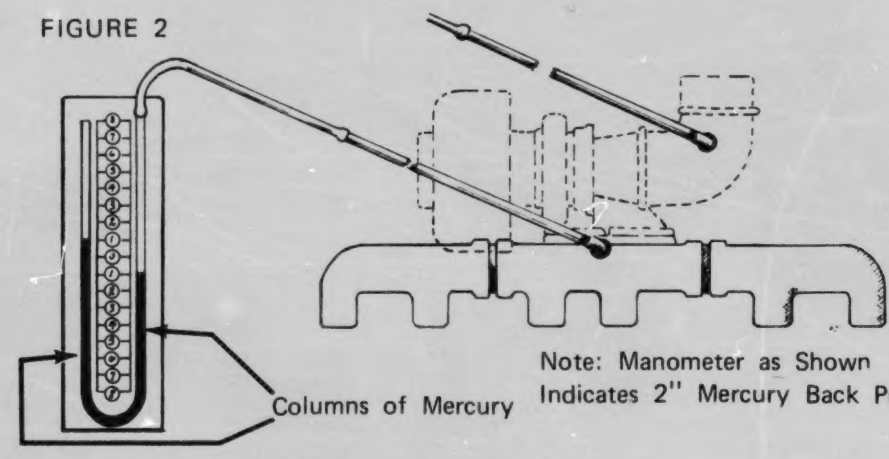
1. Remove 1/8" pipe plug in exhaust manifold

   (NOTE: If no opening is provided, drill an 11/32" hole in exhaust manifold companion flange and tap the hole to accomodate a 1/8" pipe plug.)

2. Connect the mercury manometer to the exhaust manifold (Figure 2)

   (NOTE: On turbocharged engines check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet.)

FIGURE 2



Note: Manometer as Shown Indicates 2" Mercury Back Pressure

3. Start engine and operate to normal operating temperature

4. Take back-pressure readings when engine is developing rated horsepower at governed speed

JOB SHEET #4

5. Add reading of mercury in both columns for final figure(Figure 2)

   Example: If mercury is 1 inch high in left column and 1 inch low in right column, there is 2 inches of pressure; if mercury is 1 inch high in right column and 1 inch low in left column, there is 2 inches of vacuum

6. Check the engine technical manual operating conditions for maximum permissible back pressure

C. Check air box pressure

1. Connect manometer to an air box drain tube

2. Operate the engine at manufacturer's rated load speed and note pressure readings

3. Compare readings with the engine technical manual operating conditions

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

NAME________________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. In engine service, the use of instruments to troubleshoot the engine parts to locate the cause of failure

_____b. Instrument for measuring the power output of an engine by applying a load to the engine, thereby testing the horsepower and torque

_____c. Instrument used to check the air intake system of an engine

_____d. Instrument using mercury or water in a U-tube, indicating positive or negative (vacuum) pressure by the difference in height of the two columns

_____e. Device measuring speed of rotation

_____f. Instrument for measuring temperatures beyond the range of a mercurial thermometer

1. Vacuum gauge
2. Diagnosis
3. Tachometer
4. Manometer
5. Dynamometer
6. Pyrometer

2. Arrange in order the steps in diagnosing and testing an engine by placing the correct sequence number in the appropriate blank.

_____a. Operate the machine

_____b. Reach a conclusion

_____c. Ask the operator

_____d. Inspect the machine

_____e. List the possible causes

_____f. Know the system

_____g. Test your conclusion

3. List four major checkpoints when inspecting a diesel engine.

   a. ____

   b. ____

   c. ____

   d. ____

4. Complete the following list of major checks to make when operating an engine.

   a. Gauge readings

   b. ____

   c. Smells

   d. ____

   e. Controls

   f. Power under load

   g. Idle speed

   h. ____

   i. Alternator or generator output

5. List six tests that are made with a dynamometer.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

   f. ____

6. Name three factors necessary for an engine to produce horsepower.

   a. ____

   b. ____

   c. ____

7. Select the possible causes of a diesel engine being hard to start or not starting by placing an "X" in the appropriate blanks.

______a. Low cranking speed

______b. Faulty nozzle operation

______c. Cracked or eroded distributor rotor

______d. Defective coil or condenser

______e. Air in fuel system

______f. Improper timing

______g. Water or dirt in fuel or dirty filters

______h. Too heavy oil in air cleaner

______i. No fuel or improper fuel

______j. Faulty injection pump

8. Select the possible causes of a diesel engine starting but not running by placing an "X" in the appropriate blanks.

______a. Dirt in fuel

______b. Air restrictions

______c. Clogged filter

______d. Defective coil or condenser

9. Complete the following list of items which would cause a diesel engine to misfire.

a. Water or dirt in fuel

b. Gasoline in diesel fuel

c. Air in fuel system

d. Faulty nozzle operation

e. ____

f. Nozzles not seated properly in cylinder head

g. ____

10. Select the items which would cause a diesel engine to knock by placing an "X" in the appropriate blanks.

______a. Improper injection pump timing

______b. Worn engine bearings or bushings

______c. Excessive crankshaft end play

______d. Loose bearing caps

______e. Foreign material in cylinder

______f. Restricted fuel line

11. Select the items which would cause a diesel engine to overheat by placing an "X" in the appropriate blanks.

______a. Defective radiator cap

______b. Radiator fins bent or plugged

______c. Defective thermostat

______d. Insufficient coolant

______e. Loose fan belt

______f. Cooling system limed up

______g. Overloaded engine

______h. Faulty engine timing

______i. Distributor advance mechanism stuck

______j. Engine low on oil

______k. Wrong type of fuel

______l. Faulty shutter operation (if used)

12. Circle the items which would cause a diesel engine to have lack of power.

a. Air cleaner dirty or otherwise obstructed

b. Restricted air flow in intake system

c. Restriction in fuel lines or filters

d. Wrong type of fuel

e. Frost at fuel-lock strainer

f. Governor grinds

g. Distributor points burned

h. Incorrect camshaft timing

i. Low operating temperature

j. Faulty injection pump delivery

k. Improper hitching or belting of machine

l. Valve failure

m. Incorrect valve tappet clearance

n. Low engine speed

o. Crankcase oil too heavy

p. Low compression

13. Select the items which would cause a diesel engine to use too much oil by placing an "X" in the appropriate blanks.

_____a. Crankcase oil too light

_____b. Worn pistons and rings

_____c. Worn valve guides or stem oil seals

_____d. Loose connecting rod bearings

_____e. External oil leaks

_____f. Oil pressure too high

_____g. Engine speed too high

_____h. Crankcase ventilator pump not working

_____i. Restricted air intake or breather

_____j. Excessive oil in rocker arm assembly

_____k. Oil pressure too low

14. Name two causes of high oil pressure.

a. ______________________________

b. ______________________________

15. List five causes of low oil pressure.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

16. Complete a diesel troubleshooting guide.

17. Demonstrate the ability to:

    a. Load test an engine with a dynamometer.

    b. Test engine cylinder compression.

    c. Check air intake system for restrictions.

    d. Check crankcase pressure, exhaust back pressure, and air box pressure.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

ANSWERS TO TEST

1. a. 2 d. 4
   b. 5 e. 3
   c. 1 f. 6

2. a. 3 e. 5
   b. 6 f. 2
   c. 1 g. 7
   d. 4

3. a. Water system
   b. Oil system
   c. Fuel system
   d. Electrical system

4. b. Unusual sounds
   d. Smoke
   h. Battery condition

5. Any six of the following:

   a. Engine horsepower
   b. Exhaust smoke analysis
   c. Fuel consumption
   d. Crankcase blow-by
   e. Air cleaner restriction
   f. Oil pressure
   g. Clutch operation
   h. Exhaust temperature
   i. Air box pressure
   j. Exhaust pressure

6. a. Fuel-air mixture
   b. Compression
   c. Ignition

7. a, b, e, f, g, i, j

8. a, b, c

9. e. Faulty injection pump
   g. Low compression

10. a, b, c, d, e

11. a, b, c, d, e, f, g, h, j, k, l

12. a, b, c, d, h, i, j, l, m, n, o, p

13. a, b, c, d, e, f, g, h, i, j

14. Any two of the following:

    a. Stuck relief valve
    b. Defective pressure gauge
    c. Wrong oil pump
    d. Oil too thick

15. Any five of the following:

    a. Worn bearings
    b. Poor relief valve seating
    c. Too light oil
    d. Worn oil pump
    e. Engine low on oil
    f. Loose connection or leaky seals at oil filter, pump, or cooler
    g. Defective oil pressure gauge
    h. Dilution of oil

16. Evaluated to the satisfaction of the instructor

17. Performance skills evaluated to the satisfaction of the instructor

TUNE-UP AND ADJUSTMENT
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to tune-up and service a diesel engine. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with tune-up and adjustment.
2. Complete a list of major items to include in a visual inspection checklist.
3. Demonstrate the ability to:
    a. Tune-up and service a diesel engine.
    b. Tune-up a Cummins diesel engine.
    c. Tune-up a Detroit diesel engine.
    d. Tune-up a 3400 series Caterpillar diesel engine.

TUNE-UP AND ADJUSTMENT
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Discuss unit and specific objectives.

IV. Discuss information sheet.

V. Demonstrate and discuss the procedures outlined in the job sheets.

VI. Discuss procedures for stopping a "run-away" engine.

VII. Discuss three valve adjustment methods.

VIII. Demonstrate valve wear problems.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Job sheets

    1. Job Sheet #1--Tune-Up and Service a Diesel Engine

    2. Job Sheet #2--Tune-Up a Cummins Diesel Engine

    3. Job Sheet #3--Tune-Up a Detroit Diesel Engine

    4. Job Sheet #4--Tune-Up a 3400 Series Caterpillar Diesel Engine

  D. Test

  E. Answers to test

II. References:

  A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. Chicago: American Technical Society, 1974.

  B. *Fundamentals of Service: Engines.* 5th ed. Moline, Illinois: Deere and Company, 1980.

C. *Service Manual, Detroit Diesel Engines*. Detroit, Michigan: Detroit Diesel Allison, 1975.

D. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, 1974.

E. *Engine Service Manual*. Peoria, Illinois: Caterpillar Tractor Company, 1972.

F. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

G. *Service Manual: 3406 Industrial and Marine Engine*. Peoria, Illinois: Caterpillar Tractor Company, 1979.

TUNE-UP AND ADJUSTMENT
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. Tune-up--Process of making checks and minor adjustments to improve the operation of the engine

      (NOTE: Some companies consider tune-up to be preventive maintenance.)

   B. Service--To clean, inspect, adjust, lubricate, or repair a component or part as needed

   C. Replace--To install a new or rebuilt component or part

II. Visual inspection checklist

   (NOTE: Engine should be kept as clean as possible.)

   A. Oil and water leakage

   B. Electrical system

   C. Cooling system

   D. Air intake system

   E. Fuel system

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #1--TUNE-UP AND SERVICE A DIESEL ENGINE

I. Tools and materials

- A. Basic hand tool set
- B. Compression tester with adapters
- C. Appropriate engine special tools
- D. Torque wrench
- E. Nozzle tester
- F. Radiator and radiator cap tester
- G. Thermostat tester
- H. Dynamometer
- I. Appropriate engine service manuals
- J. Dynamometer technical manual
- K. Battery service manual
- L. Safety glasses

II. Procedure

(NOTE: In the spaces to the right of each step, indicate the action which was taken. Inspection is the preliminary step prior to either servicing or replacing the component. Serviced means that the component or component part has been cleaned, inspected, adjusted, lubricated or repaired as needed. Replaced means that new or rebuilt components or component parts have been installed.)

	Inspected	Serviced	Replaced
A. Service air intake and exhaust system			
1. Clean pre-cleaner (if used)	☐	☐	☐
2. Remove and clean air cleaner	☐	☐	☐
3. Swab out inlet pipe in air cleaner body	☐	☐	☐
4. Inspect exhaust system and muffler	☐	☐	☐
5. Check crankcase ventilating system for restrictions	☐	☐	☐

JOB SHEET #1

		Inspected	Serviced	Replaced
B.	Service basic engine			
1.	Recheck air intake for restrictions	☐	☐	☐
2.	Check radiator for air bubbles or oil indicating compression or oil leaks	☐	☐	☐
3.	Check for leakage at cylinder head gasket	☐	☐	☐
4.	Retighten cylinder head cap screws	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)	☐	☐	☐
5.	Adjust valve clearance	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
6.	Check compression pressure in each cylinder	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
C.	Service fuel system			
1.	Check fuel lines for leaks or restrictions	☐	☐	☐
2.	Clean fuel pump sediment bowl	☐	☐	☐
3.	Test fuel pump pressure	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
4.	Check speed control linkage	☐	☐	☐
5.	Service diesel fuel filters	☐	☐	☐
6.	Check diesel injection pump	☐	☐	☐

JOB SHEET #1

		Inspected	Serviced	Replaced
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
7.	Check and clean diesel injection nozzles	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
8.	Bleed diesel fuel system	☐	☐	☐
9.	Check diesel injection pump timing	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
D.	Service lubrication system			
1.	Check operation of pressure gauge or light	☐	☐	☐
2.	Service oil filter	☐	☐	☐
3.	Check condition of crankcase oil	☐	☐	☐
4.	Check engine oil pressure	☐	☐	☐
E.	Service cooling system			
1.	Check water pump for leaks and excessive shaft end play	☐	☐	☐
2.	Inspect radiator hoses	☐	☐	☐
3.	Clean and flush cooling system	☐	☐	☐
4.	Test thermostat and pressure cap	☐	☐	☐
5.	Test radiator for leaks	☐	☐	☐
6.	Check condition of fan belt			
F.	Service electrical system			

JOB SHEET #1

	Inspected	Serviced	Replaced
1. Service battery			
a. Clean battery, cable, terminals, and battery box	☐	☐	☐
b. Tighten battery cables and battery hold-down	☐	☐	☐
c. Check specific gravity of electrolyte and add water to proper level	☐	☐	☐
d. Make high discharge or load test of battery condition	☐	☐	☐
(NOTE: Refer to appropriate job sheet or battery service manual.)			
2. Service generator or alternator			
a. Check belt tension	☐	☐	☐
b. Test alternator or generator output	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
3. Service starting circuit			
a. Check safety starter switch	☐	☐	☐
b. Check current draw of starting motor	☐	☐	☐
4. Service clutch free travel--Check free travel at clutch pedal or lever (if used)	☐	☐	☐
(NOTE: Refer to appropriate service manual.)			

JOB SHEET #1

	Inspected	Serviced	Replaced
G. Check engine performance by conducting a load test with a dynamometer (NOTE: Refer to appropriate job sheet or dynamometer technical manual.)	☐	☐	☐

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #2--TUNE-UP A CUMMINS DIESEL ENGINE

I. Tools and materials

   A. Basic hand tool set

   B. Cummins special tools

   C. Torque wrench

   D. Thickness gauge

   E. Cleaning solvent

   F. Diesel fuel

   G. Shop towels

   H. Safety glasses

II. Procedure

   A. Adjust injector

   (NOTE: Dial indicator method may also be used.)

      1. Remove hood if applicable

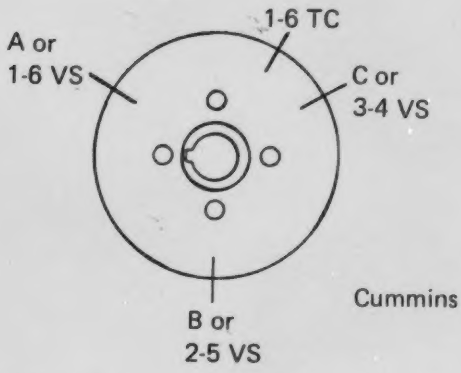
      2. Remove valve cover

      (NOTE: Check the inside of the covers for presence of water condensation.)

      3. Loosen the injector rocker lever adjusting nut on all cylinders

      4. Rotate engine until the first "VS" mark on the pulley or damper is aligned with the index mark on the housing (Figure 1)

FIGURE 1



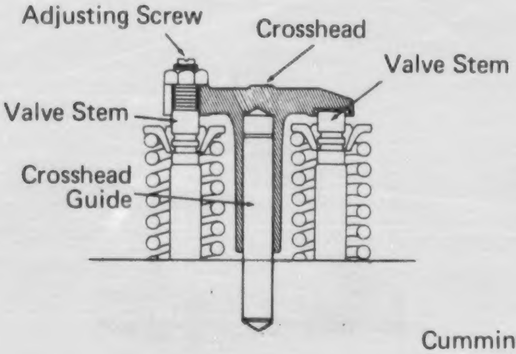
Courtesy of
Cummins Engine Company, Inc.

JOB SHEET #2

5. Use an inch/lb torque wrench and in a near continuous motion draw the injector adjusting screw to its specified torque

B. Adjust valve crosshead (Figure 2)

FIGURE 2



Courtesy of
Cummins Engine Company, Inc.

1. Loosen the adjusting screw lock-nut and back off the adjusting screw one turn
2. Use light finger pressure at the rocker lever contact surface to hold crosshead in contact with the valve stem nearest the push-rod
3. Turn adjusting screw down until it contacts its mating valve stem
4. For new crosshead and guides, advance the adjusting screw 20° more to straighten the stem in its guide; worn crosshead may be advanced 30° to straighten the stem in its guide
5. Hold the adjusting screw in this position and tighten locknut to specified torque

C. Adjust valve

(NOTE: On engines equipped with compression release apparatus be sure that the shaft is fully released before adjusting valves.)

1. Loosen rocker arm locknuts
2. Using a specified thickness gauge, turn the adjusting screw to obtain a good contact on the thickness gauge
3. Adjust both the intake and exhaust valves
4. Tighten locknuts

JOB SHEET #2

5. Bar engine over in direction of rotation and firing order, and set the rest of the injectors, crossheads, and valves

6. Install valve covers

D. Check fuel pump filter screens

   1. Remove cap

   2. Lift screens out and inspect magnet for metal particles

      (NOTE: Large particles show excessive wear in gear pump.)

   3. Clean screen

   4. Reinstall and torque to specified limits

E. Adjust engine idle speed

   1. Low idle

      a. Attach tachometer to the drive outlet on top of the fuel pump

      b. Remove pipe plug from spring pack cover

      c. Set engine idle to manufacturer's specifications

         (NOTE: Engine idle speed may change when the housing fills with fuel.)

   2. Adjust high idle

      a. Attach tachometer to the drive outlet on top of the fuel pump

         (NOTE: If high idle has to be changed, consult the appropriate shop manual or service bulletin.)

      b. Shut engine down

      c. Remove spring pack cover

      d. Remove snap ring

      e. Increase or decrease shims to regulate engine speed; each .001 inch shim will increase or decrease engine speed by 2 rpm

         (NOTE: Never set maximum speed to please an operator.)

JOB SHEET #2

3. Check pump operation

    a. Check manifold pressure

        1) Install gauge at the shut-off valve

        2) Operate engine 400 rpm below governed speed

        3) Accelerate to governed speed

        4) Observe gauge for specified pressure

    b. Check inlet restriction

        1) Install vacuum gauge at gear pump inlet

        2) Operate warmed up engine 5 minutes after installation of gauge

        3) Observe gauge readings

        (NOTE: Readings should not exceed 8" to 8.5" vacuum.)

    c. Check suction side, air leakage

        1) Shut down engine

        2) Install sight gauge on pump inlet side and operate engine

        3) Check for air bubbles

        (NOTE: Bubbles indicate an air leak.)

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #3--TUNE-UP A DETROIT DIESEL ENGINE

I. Tools and materials

- A. Basic hand tool set
- B. Cleaning solvent
- C. GM diesel special tune-up tools
- D. Torque wrench
- E. Thickness gauge
- F. Shop towels
- G. Diesel fuel
- H. Engine service manual
- I. Safety glasses

II. Procedure

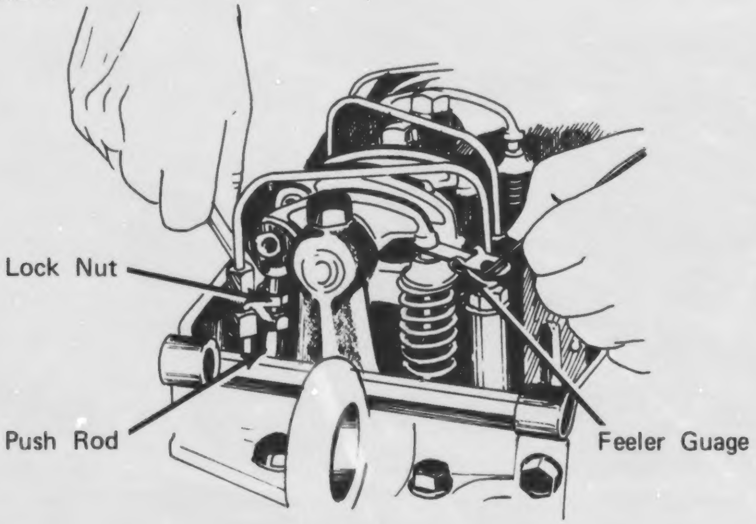
- A. Adjust exhaust valve clearance
  - 1. Adjust valves on cold engine
    - a. Remove loose dirt from valve rocker cover
    - b. Remove the cover
    - c. Place governor speed control lever in the idle speed position
    - d. Position engine by rotating the crankshaft until the injector follower is fully depressed on the cylinder to be adjusted

      (CAUTION: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as the bolt will be loosened.)
    - e. Loosen the exhaust valve rocker arm pushrod locknut

JOB SHEET #3

f. Place a .013" feeler gauge between the valve stem and the valve rocker arm (Figure 1)

FIGURE 1



g. Adjust the pushrod to obtain a smooth pull on feeler gauge

h. Remove feeler gauge, hold the pushrod with a 5/16" wrench and tighten the locknut with a 1/2" wrench

i. Recheck the clearance

(NOTE: If the adjustment is correct, the .011" feeler gauge will pass freely between the valve stem and valve rocker arm but the .013" feeler gauge will not pass through. This is referred to as "go-no go" measurement.)

j. Rotate engine in the direction of travel and adjust remaining valves in same manner as above

(CAUTION: Remove device used to bar engine before starting.)

2. Adjust valves on hot engine

a. Start engine and bring to normal operating temperature (160-185°)

b. Recheck exhaust valve clearance with feeler gauge

(NOTE: Valve clearance will decrease when engine is hot, therefore, "go-no go" clearance will be .008" and .010")

JOB SHEET #3

c. Readjust the pushrod, if necessary

d. Adjust and check the remaining exhaust valves in the same manner as above

Time fuel injector

(NOTE: Adjust the exhaust valve clearance before timing injectors.)

1. Place governor speed control lever in idle speed position

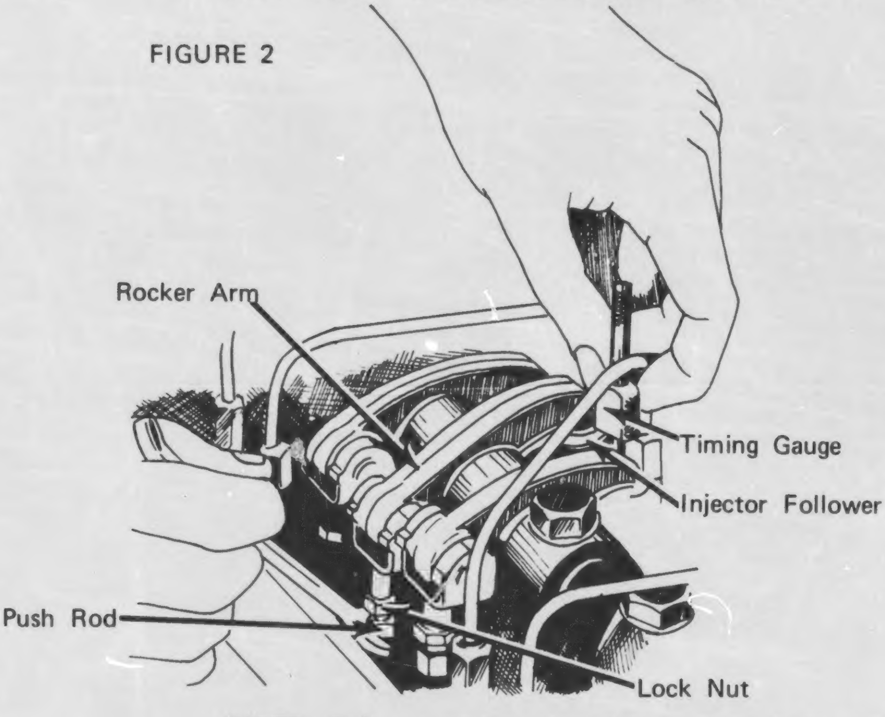
   (NOTE: Secure stop lever in stop position, if used.)

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed

   (CAUTION: If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft on a left-hand direction rotation or the bolt may be loosened.)

3. Place the small end of the injector timing gauge in the hole provided in the top of the injector body with the flat of the gauge toward the injector follower (Figure 2)

FIGURE 2



(NOTE: Refer to service manual for correct timing gauge and timing dimension for the injector being timed.)

JOB SHEET #3

4. Loosen the injector rocker arm pushrod locknut

5. Turn the pushrod

6. Adjust the injector rocker arm until the extended part of the gauge will just pass over the top of the injector follower

7. Hold the pushrod

8. Tighten the locknut

   (NOTE: Check the adjustment and, if necessary, readjust the pushrod.)

9. Time the remaining injectors in the same manner as outlined above

10. Install the valve rocker cover, using a new gasket

C. Adjust limiting speed mechanical governor and injector rack control

(NOTE: These procedures should be completed after adjusting the exhaust valves and timing the fuel injectors.)

1. Adjust governor gap--Single weight governor

   a. Start engine and bring to operating temperature

   b. Stop engine

   c. Loosen the lever and disconnect the fuel modulator, the power control device, the load limiting device, or the air cylinder link, if the engine is so equipped

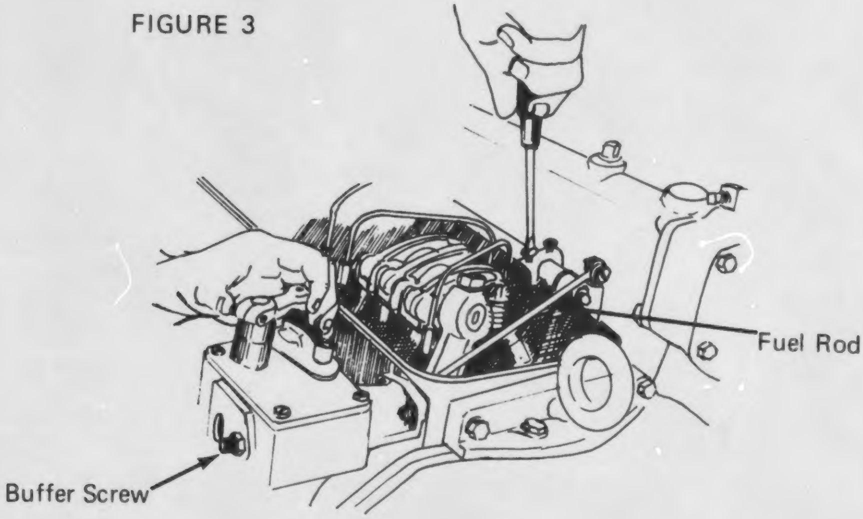
   d. Remove the two attaching bolts

   e. Withdraw the governor high speed spring retainer cover

JOB SHEET #3

f. Back out the buffer screw until it extends approximately 5/8" from the locknut (Figure 3)

FIGURE 3



g. Start the engine

h. Loosen the idle speed adjusting screw locknut

i. Adjust the idle screw to obtain the desired idle speed

j. Hold the screw and tighten the locknut to retain the adjustment

(NOTE: The recommended idle speed is 550 rpm for single weight governors, but may vary with special engine applications.)

k. Stop the engine

l. Remove the governor cover and lever assembly

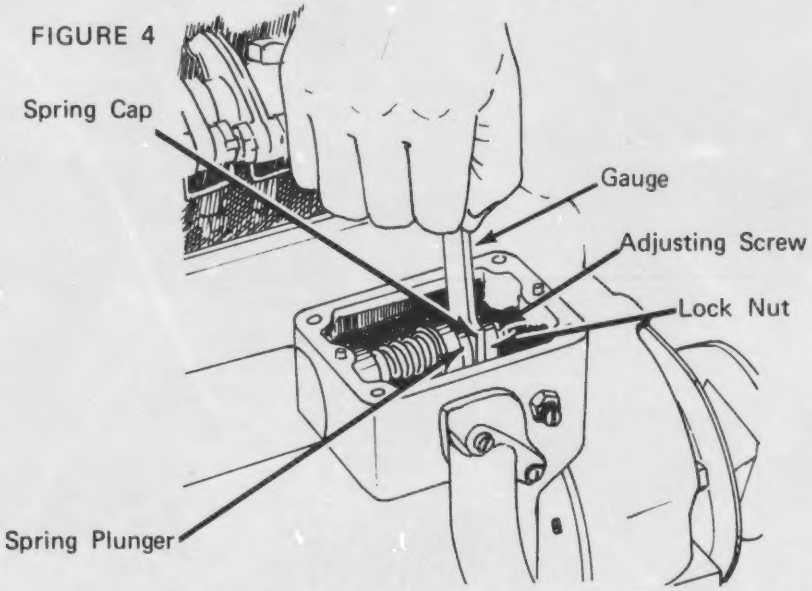
m. Clean and remove the valve rocker cover

n. Remove the fuel rod from the differential lever and the injector control tube lever

JOB SHEET #3

o. Check the gap between the low speed spring cap and the high speed spring plunger with gauge (Figure 4)

FIGURE 4



p. Loosen the locknut and turn the gap adjusting screw until a slight drag is felt on the gauge, if required

q. Hold the adjusting screw

r. Tighten the locknut

s. Recheck the gap and readjust if necessary

t. Install the fuel rod between the governor and injector control tube lever

u. Install the governor cover and lever assembly

2. Adjust governor gap on a double weight governor

    a. Start engine

    b. Bring to operating temperature

    c. Stop engine

    d. Remove the two attaching bolts

    e. Withdraw the governor high speed spring retainer cover

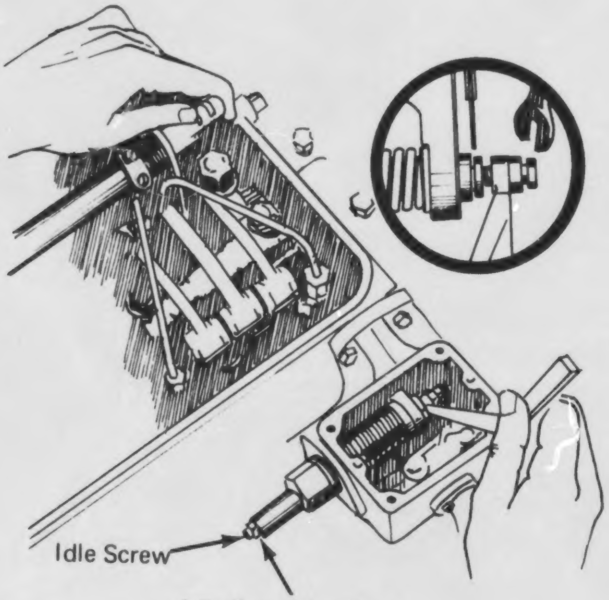
    f. Back out the buffer screw until it extends approximately 5/8" from the locknut (Figure 3)

JOB SHEET #3

g. Start the engine

h. Loosen the idle speed adjusting screw locknut (Figure 5)

FIGURE 5



i. Adjust the idle screw to obtain the desired idle speed

j. Hold the screw and tighten the locknut to retain the adjustment

(NOTE: The recommended idle speed is 450 rpm for double weight governors, but may vary with special engine applications.)

k. Stop the engine

l. Remove the governor cover and lever assembly

m. Clean and remove the valve rocker cover

n. Remove the fuel rod from the differential lever and the injector control tube lever

o. Start and run the engine between 800 and 1000 rpm by manual operation of the control tube lever

(CAUTION: Do not overspeed the engine.)

JOB SHEET #3

p. Check the gap between the low speed spring cap and the high speed plunger with a .0015" feeler gauge (Figure 5)

(NOTE: If the gap setting is incorrect, loosen the locknut and adjust the gap adjusting screw.)

q. Hold the gap adjusting screw

r. Tighten the locknut

s. Recheck the governor gap

t. Stop the engine

u. Install the fuel rod between the differential lever and the control tube lever

v. Install the governor cover and lever assembly

D. Position injector rack control levers

1. Disconnect any linkage attached to the governor speed control lever
2. Loosen the idle speed adjusting screw locknut
3. Back out the idle speed adjusting screw until 1/2" of the threads project from the locknut when the nut is against the high speed plunger
4. Loosen all of the inner and outer injector rack control lever adjusting screws

   (NOTE: On engines equipped with a yield link type fuel rod, attach a small "C" clamp at the shoulder of the rod to prevent the yield spring from compressing while adjusting the injector rack control levers.)

5. Move the governor speed control lever to the full-fuel position
6. Hold the lever in that position with light finger pressure
7. Turn the inner adjusting screw on the no. 1 injector rack control lever down until a slight movement of the control tube is observed or a step up in effort is noted.

   (NOTE: This will place the no. 1 injector rack in the full-fuel position.)

8. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube

JOB SHEET #3

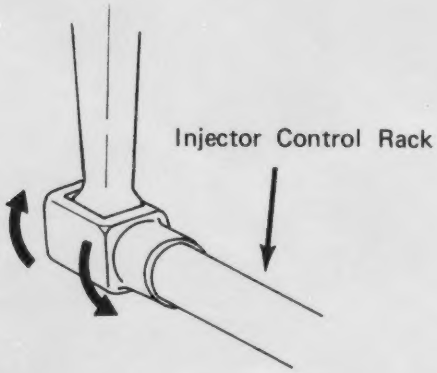
9. Alternately tighten both the inner and outer adjusting screws

   (CAUTION: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws in 24-36 in-lbs.)

10. Hold the speed control lever in the full-fuel position

11. Press down on the injector rack with a screwdriver or finger tip and note "rotating" movement of the injector control rack when the speed control lever is in the full-fuel position (Figure 6)

FIGURE 6

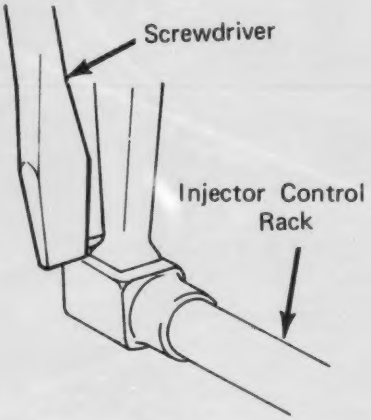


12. Hold the speed control lever in the full-fuel position

13. Use a screwdriver to press downward on the injector control rack

    (NOTE: The rack should tilt downward and when the pressure of the screw drive is released, the control rack should "spring" back upward. See Figure 7.)

FIGURE 7



JOB SHEET #3

14. Check to see if rack returns to its original position

    (NOTE: If it is too loose, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. If too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.)

15. Disconnect the fuel rod from the injector control tube

16. Hold the No. 1 injector in the full-fuel position

17. Turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube

18. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube

19. Alternately tighten both the inner and outer adjusting screws

20. Recheck the No. 1 injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the No. 2 injector

    (NOTE: If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.)

21. Position the remaining injector rack control levers

22. Connect the fuel rod to the injector control tube lever

23. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting the engine

24. Tighten the locknut

    (NOTE: Remove the C clamp from the fuel rod on units equipped with a yield link.)

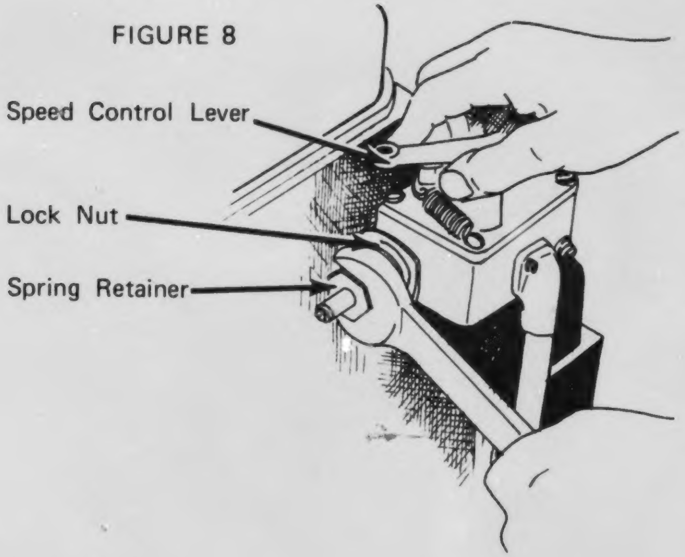
E. Adjust maximum no-load engine speed

   1. Loosen the locknut

JOB SHEET #3

2. Back off the high speed spring retainer approximately five turns (Figure 8)

FIGURE 8



3. Place the speed control lever in the full-fuel position with the engine at operating temperature and no-load on the engine

4. Turn the high speed spring retainer in until the engine is operating at the recommended no-load speed

5. Hold the high speed spring retainer

6. Tighten the locknut

F. Adjust idle speed

1. Remove the spring housing to uncover the idle speed adjusting screw

2. Turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed

   (NOTE: The recommended idle speed is 550 rpm for single weight governors and 450 rpm for double weight governors, but may vary with engine applications.)

3. Hold the idle screw

4. Tighten the locknut

5. Install the high speed spring retainer

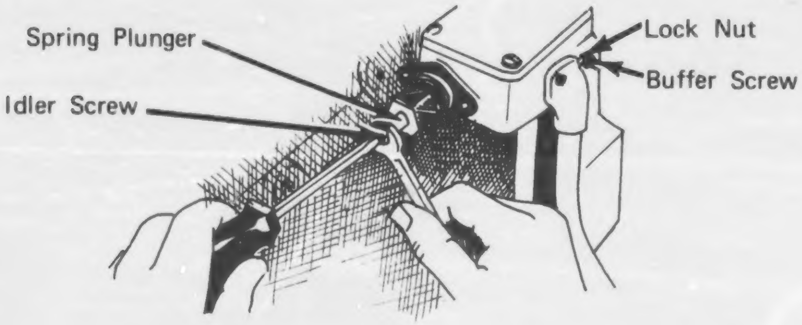
6. Retain with the two bolts

JOB SHEET #3

G. Adjust buffer screw

1. Turn the buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates the engine roll (Figure 9)

FIGURE 9



(NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.)

2. Hold the buffer screw

3. Tighten the locknut

4. Recheck the maximum no-load speed

(NOTE: If it has increased more than 25 rpm.,back off the buffer screw until the increase is less than 25 rpm.)

TUNE-UP AND ADJUSTMENT
UNTI III

JOB SHEET #4--TUNE-UP A 3400 SERIES CATERPILLAR DIESEL ENGINE

I. Tools and materials

- A. Basic hand tool set
- B. Caterpillar special tools
- C. Appropriate service manual
- D. Shop towels
- E. Compressed air source
- F. Feeler gauge
- G. Safety glasses
- H. Timing turning tool

II. Procedure

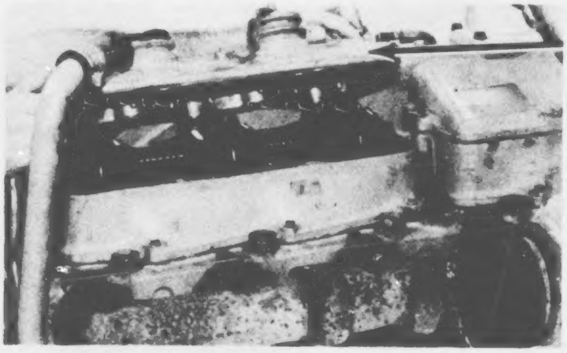
(CAUTION: Follow all shop safety procedures.)

A. Adjust valve lash

(NOTE: Engine should be run until it reaches normal operating temperature.)

1. Stop the engine
2. Clean the top of the cylinder head and the base of the valve cover
3. Remove the brackets holding the lines to the instrument panel gauges (Figure 1)

FIGURE 1



Valve Cover

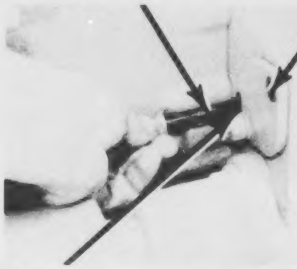
JOB SHEET #4

4. Remove the valve cover

   (NOTE: Keep dirt from falling inside the engine block or into the valve mechanism, as the valve cover is removed.)

5. Keep timing bolt in storage on flywheel housing; it can be installed in either the left side of the engine at location 1 (Figure 2) or in the right side of the engine at location 2 (Figure 3)

FIGURE 2

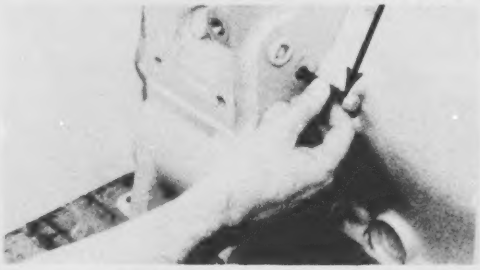


Timing Tool

Timing Tool Installed Left Side Location

Timing Tool Storage Locations

FIGURE 3



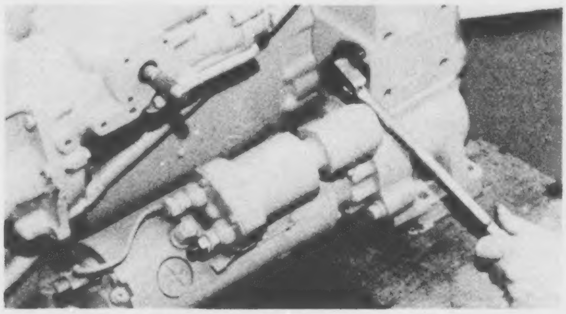
Timing Tool Installed Right Side Location

(NOTE: No. 1 piston at top center (TC) on the compression stroke is the starting point of all timing procedures.)

6. Install engine turning tool into housing until shoulder of tool is against housing

7. Attach a 1/2" drive ratchet to tool and turn flywheel while holding timing bolt in position in hole locations 1 or 2 where plug was removed (Figure 4)

FIGURE 4



8. Stop rotation when timing bolt can be installed in threaded hole of flywheel

9. Check to see if No. 1 piston is on the compression stroke; look at the valves of No. 1 cylinders, the valves will be closed if No. 1 cylinder is on the compression stroke

10. Check the rocker arm; you should be able to move it up and down with your hand

JOB SHEET #4

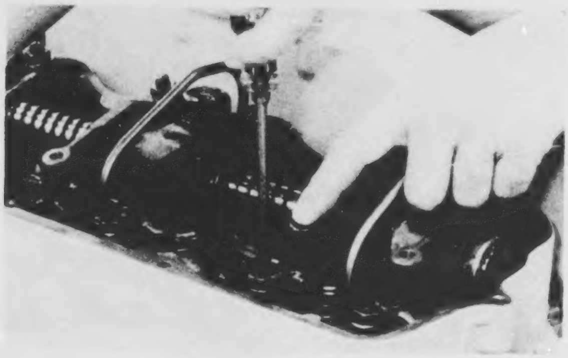
11. If No. 1 piston is not on the compression stroke turn the flywheel 360° and install the timing bolt

B. Set bridge adjustment

1. Loosen the locknut for the adjustment screw and loosen the adjustment screw several turns

2. Put pressure on the bridge with a finger to keep the bridge in contact with the valve stem opposite the adjustment screw (Figure 5)

FIGURE 5



3. Turn the adjustment screw clockwise until it makes contact with the valve stem

4. Turn adjustment screw 30° more in a clockwise direction to make the bridge straight on the dowel, and to compensate for the clearance in the threads of the adjustment screw

5. Hold the adjustment screw in this position and tighten the locknut to 22 lb. ft.

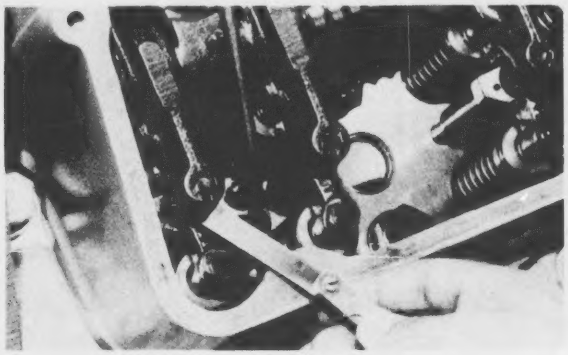
6. Put engine oil at the point where rocker arm makes contact with the bridge

JOB SHEET #4

C. Set valve lash

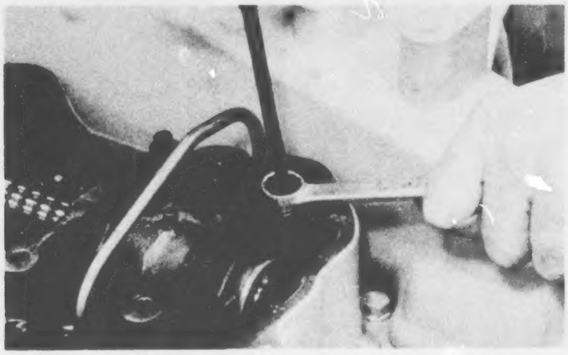
(NOTE: Valve clearance is measured between the rocker arm and the bridge for the valves.) (Figure 6)

FIGURE 6



1. Put No. 1 piston at top center (TC) on the compression stroke, and loosen locknuts
2. Make an adjustment to the valve clearance on the intake valves for cylinders 1, 2, and 4
3. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1, 3, and 5 (Figure 7)

FIGURE 7



JOB SHEET #4

4. Tighten the nut for the valve adjustment screw to 22 lb. ft. after each adjustment and recheck the adjustment

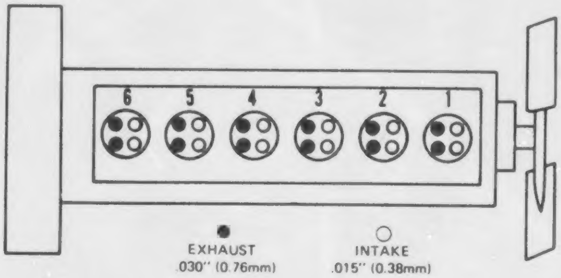
5. Remove the timing bolt and turn the flywheel 360° in the direction of engine rotation. This will put No. 6 piston at top center (TC) on the compression stroke; install the timing bolt in the flywheel

6. Make an adjustment to the valve clearance on the intake valves for cylinders 3, 5, and 6 (Figure 7)

7. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2, 4, and 6

8. Remove the timing bolt from the flywheel when all adjustments to the valve clearances have been made (Figure 8)

FIGURE 8



Cylinder and Valve Location

D. Check valve rotation

1. Start the engine

2. Move the governor control to low idle position

3. Watch the serrations on each valve retainer

   (NOTE: Each valve retainer should turn slightly each time the valve closes.)

4. Stop the engine

5. Inspect the valve cover

6. Install a new gasket, if necessary

7. Install the valve cover

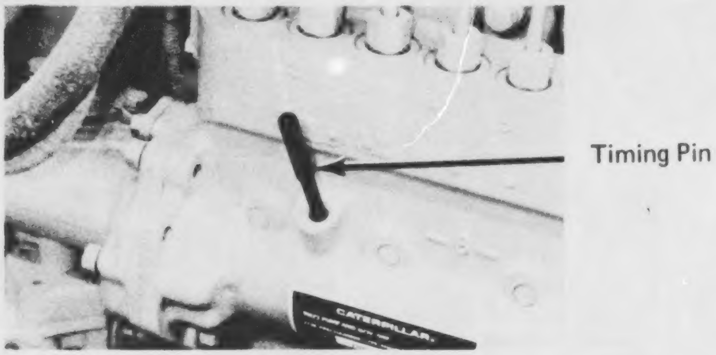
8. Install the flywheel housing timing cover

JOB SHEET #4

E. Check fuel injection pump timing

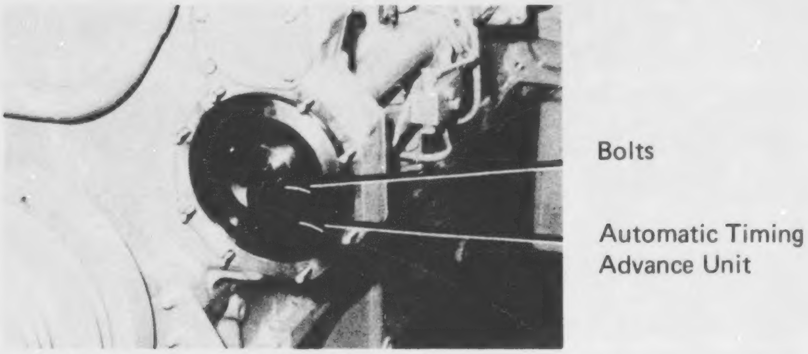
1. Install timing pin through the hole in the pump housing and into the notch in the camshaft (Figure 9)

FIGURE 9



2. Loosen four bolts (one bolt on earlier engines) holding the automatic timing advance unit to the drive shaft for the fuel injection pump (Figure 10)

FIGURE 10



3. Hit the automatic timing advance unit with a soft hammer to make it come loose from the end of the drive shaft for the fuel injection pump

   (NOTE: Be sure it will move freely on the end of the shaft.)

4. Put No. 1 piston at top center (TC) on the compression stroke

5. Tighten the four bolts evenly to 25 lb. ft.; remove timing pin and tighten bolts evenly to 50 lb. ft.

JOB SHEET #4

6. Tighten bolts to a last torque of 100 lb. ft.

7. Remove the timing bolt from the flywheel

8. Turn the crankshaft two complete revolutions and check the timing again to see that timing is correct

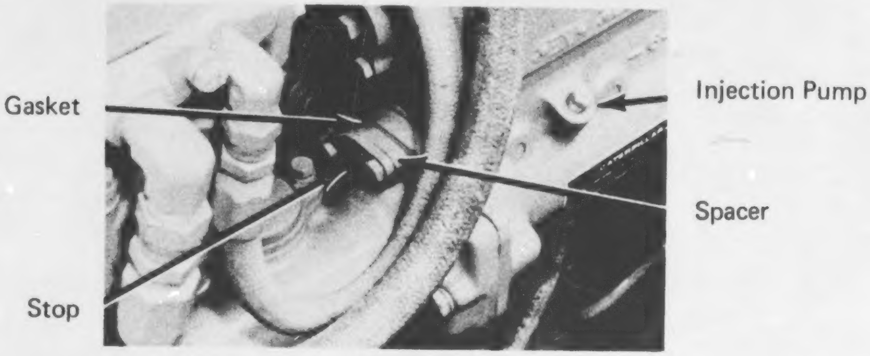
9. Check timing; if it is not correct, do the above procedure again

F. Set fuel rack, dial indicator, and circuit tester

(NOTE: Always shut down the engine before adjusting rack setting.)

1. Remove stop, spacer, and both gaskets from the drive housing for the fuel injection pump (Figure 11)

FIGURE 11

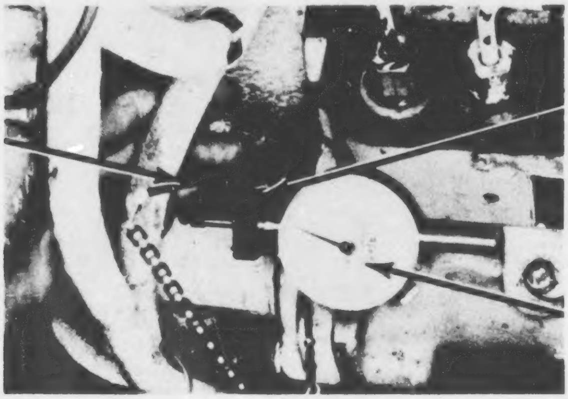


2. Disconnect the governor control linkage to let the governor lever move freely through its full travel

JOB SHEET #4

3. Install the bracket group and dial indicator on the drive housing for the fuel injection pump (Figure 12)

FIGURE 12


Spacer
Bracket Group
Dial Indicator

4. Make sure the governor lever is in the "shut off" position, then put the spacer of the bracket group over the rod that makes contact with the rack

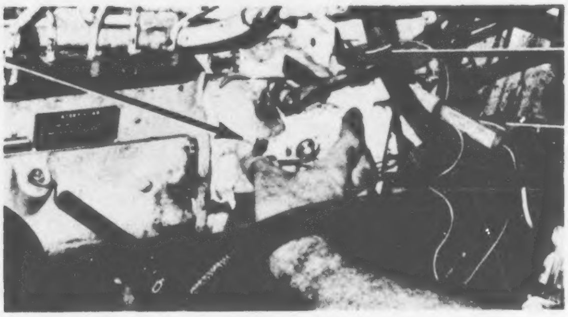
5. Put pressure on the end of the rod that makes contact with the rack to hold spacer in position while dial indicator setting is made

6. Put the dial indicator on zero

7. Remove the spacer from the rod that makes contact with the rack

8. Connect the clip end of the circuit tester to the brass terminal on the governor housing (Figure 13)

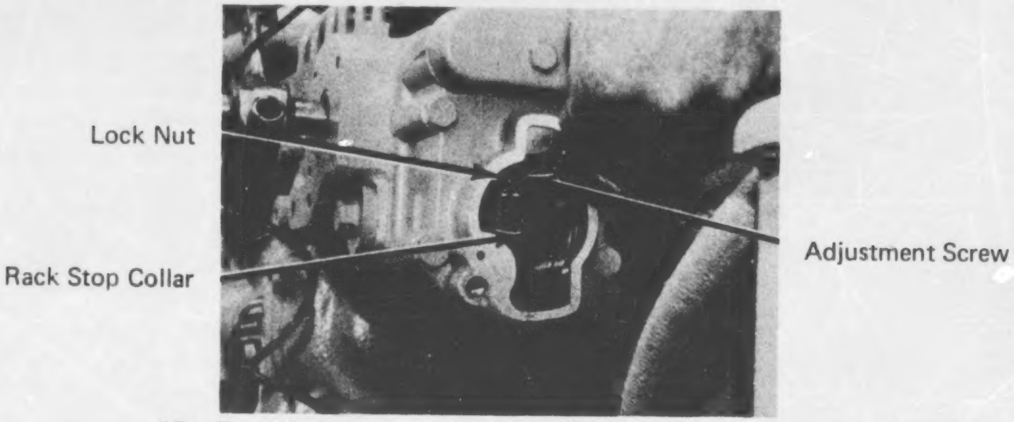
FIGURE 13


Governor Lever
Brass Terminal
Circuit Tester

JOB SHEET #4

9. Put the other end of the tester to a good ground
10. Turn governor lever (Figure 11) in the "fuel-on" direction until the light in the tester comes on
11. Move the governor lever toward the "shut-off" position until the test light goes out
12. Turn the governor lever slowly toward "fuel-on" until the test light has a minimum light output; in this position rack stop collar is just making contact with the torque spring or stop bar (Figure 14)

FIGURE 14



13. Read the measurement on the dial indicator
14. Check the rack setting information to find the correct measurement for rack setting
15. Remove the cover, or air-fuel ratio control (if so equipped), from the rear of the governor if an adjustment is necessary
16. Loosen locknut and turn adjustment screw to change the fuel rack setting if an adjustment to the fuel rack is necessary (Figure 12)
17. Tighten locknut to 9 lb. ft. after the adjustment procedure is done
18. Install the cover or air-fuel ratio control (if so equipped)

G. Adjust governor

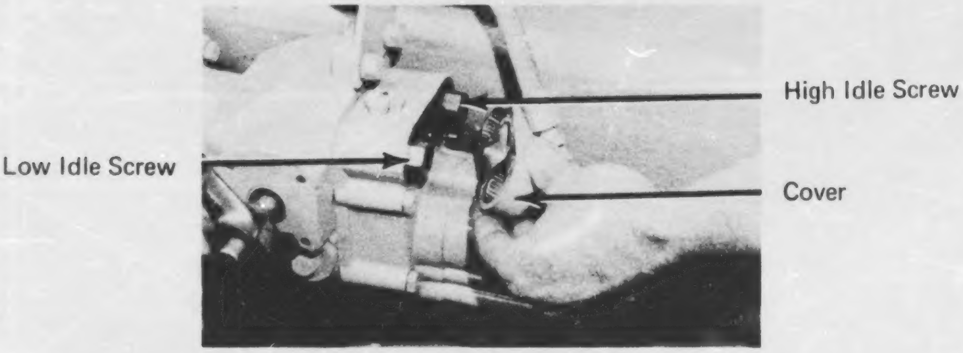
(CAUTION: Only competent personnel should attempt to adjust the low and high idle rpm.)

(NOTE: Consult the appropriate service manual for the low and high idle rpm and rack setting dimension.)

JOB SHEET #4

1. Move the governor linkage to "low idle" position and turn screw to adjust the "low idle" rpm (Figure 15)

FIGURE 15



(NOTE: Engine rpm must be checked with an accurate tachometer.)

2. Increase the engine speed and then return linkage back to "low idle" position to check the setting again
3. Move the governor linkage to "high idle" position and turn "high idle" screw to adjust "high idle" rpm
4. Move the governor control to reduce engine speed, then move the linkage to "high idle" and check the setting again when the specific rpm setting is made
5. Repeat this procedure until rpm setting is correct
6. Install the cover on top of the governor when governor adjustment is correct
7. Install a new wire and seal to cover bolt

TUNE-UP AND ADJUSTMENT
UNIT III

NAME ____________________

TEST

1. Define terms associated with tune-up and adjustment.

   a. Tune-up-- ____________________

   b. Service-- ____________________

   c. Replace-- ____________________

2. Complete the following list of major items to include in a visual inspection checklist.

   a. Oil and water leakage

   b. ____________________

   c. Cooling system

   d. Air intake system

   e. ____________________

3. Demonstrate the ability to:

   a. Tune-up and service a diesel engine.

   b. Tune-up a Cummins diesel engine.

   c. Tune-up a Detroit diesel engine.

   d. Tune-up a 3400 series Caterpillar diesel engine.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

TUNE-UP AND ADJUSTMENT
UNIT III

ANSWERS TO TEST

1. a. Process of making checks and minor adjustments to improve the operation of the engine
   b. To clean, inspect, adjust, lubricate, or repair a component or part as needed
   c. To install a new or rebuilt component or part

2. b. Electrical system
   e. Fuel system

3. Performance skills evaluated to the satisfaction of the instructor

ENGINE STORAGE
UNIT IV

UNIT OBJECTIVE

After completion of this unit,the student should be able to define temporary and permanent engine storage and demonstrate the ability to prepare an engine for temporary storage, prepare an engine for permanent storage, and prepare a stored engine for service. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with engine storage.
2. Select true statements concerning the effects of climate on an engine in storage.
3. List five systems that must be protected during permanent storage.
4. Demonstrate the ability to:
    a. Prepare an engine for temporary storage.
    b. Prepare an engine for permanent storage.
    c. Prepare a stored engine for service.

ENGINE STORAGE
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Discuss unit and specific objectives.

IV. Discuss information sheet.

V. Demonstrate and discuss the procedures outlined in the job sheets.

VI. Have students make a list of items necessary to store an engine.

VII. Have students make a list of parts to be coated.

VIII. Have students make a list of items necessary to bring an engine out of storage.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Job sheets

    1. Job Sheet #1--Prepare Engine for Temporary Storage

    2. Job Sheet #2--Prepare Engine for Permanent Storage

    3. Job Sheet #3--Prepare a Stored Engine for Service

  D. Test

  E. Answers to test

II. References:

A. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, 1974.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc. 1982.

ENGINE STORAGE
UNIT IV

INFORMATION SHEET

I. Terms and definitions

   A. Temporary storage--Protection provided to an engine against rust and corrosion which will be out of service from four weeks to six months

   B. Permanent storage--Protection provided to an engine from rust and corrosion which will be out of service over six months

II. Effects of climate on an engine in storage

   A. Unpainted machine surfaces are subject to rust and corrosion

   B. Rate of corrosion varies with climatic condition

III. Systems protected during permanent storage

   A. Lubricating

   B. Cooling

   C. Fuel

   D. Crankcase

   E. External parts

ENGINE STORAGE
UNIT IV

JOB SHEET #1--PREPARE AN ENGINE FOR TEMPORARY STORAGE

I. Tools and materials

   A. Basic hand tool set

   B. Portable container of diesel fuel

   C. Portable container of preservative oil, U.S. Military Specification MIL-L-644, Type P-9

   D. SAE #10 lubricating oil

   E. Hand or power sprayer

   F. Engine

   G. Appropriate service manual

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Start engine

   B. Increase speed gradually to 1200 rpm until engine is thoroughly warm

   C. Stop engine

   D. Disconnect both fuel lines at fuel supply tank (the line to engine fuel filter and the injector drain line)

   E. Fill two portable containers, one with regular diesel fuel and a second with preservative oil, U.S. Military Specification MIL-L-644, Type P-9

   F. Start the engine with the fuel line to the filter and engine, pulling fuel from the can with regular fuel

      (NOTE: The injector drain line can flow into the container with regular fuel.)

   G. Switch the fuel line to the container with the preservative oil after engine is running smoothly at idle

   H. Operate five to ten minutes on the preservative oil

   I. Stop the engine and reconnect the fuel lines to the supply tank

JOB SHEET #1

J. Drain oil sump, fuel filters, and fuel tank and reinstall drain plugs

(NOTE: New oil may be added or sump may remain empty until engine is ready for use.)

K. Tag engine with warning tag, if sump remains empty

L. Remove engine air line from air cleaner to intake manifolds

M. Turn fuel pump manual shut-off valve to "off" so engine will not start

N. Spray SAE #10 lubricating oil into intake manifold and air compressor with hand or power sprayer while bar cranking engine

O. Cover all intake manifold openings with tape to prevent entrance of dirt and moisture

P. Cover all engine openings, including coolant inlets, cylinder block, oil breather, and crankcase

Q. Drain coolant from cooling system unless it is permanent type antifreeze with rust inhibitor added

R. Store engine in a place protected from weather where air is dry and temperature uniform

S. Bar engine crankshaft two or three revolutions every three to four weeks

ENGINE STORAGE
UNIT IV

JOB SHEET #2--PREPARE AN ENGINE FOR PERMANENT STORAGE

I. Tools and materials

A. Basic hand tool set

B. Preservative oil, U.S. Military Specification MIL-L-21260, Type P-10, Grade SAE #30

C. Preservative oil, U.S. Military Specification MIL-L-64, Type P-9

D. Preservative oil, U.S. Military Specification MIL-C-16173C, Type P-2, Grade 1 or 2

(NOTE: Consult the manufacturer of the preservative oil or compound for the proper grade and kind of oil for preservation of the engine if there is a question regarding the correct oil.)

E. Two portable containers

F. Heavy paper

G. Tape

H. Oil spray can or brush

I. Engine

J. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Make sure engine is thoroughly clean)

A. Start engine, gradually increase speed to 1200 rpm or a fast idle, with no load, and operate until the engine is thoroughly warm

B. Stop engine and drain old oil

C. Fill crankcase to full mark on bayonet gauge or dipstick with preservative oil, U.S. Military Specification MIL-L-21260, Type P-10, Grade 2 SAE #30

D. Disconnect both fuel lines at fuel supply tank (the line to engine fuel filter and the injector drain line

JOB SHEET #2

E. Fill two portable containers, one with regular diesel fuel and a second with preservative oil U.S. Military Specification MIL-L-644 Type P-9

F. Start the engine with the fuel line to the filter and engine pulling fuel from the can with regular fuel

(NOTE: The injector drain line can flow into the container with regular fuel.)

G. Switch the fuel line to the container with preservative oil after the engine is started and running smoothly at idle

H. Operate five to ten minutes on the preservative oil

I. Stop the engine and reconnect the fuel lines to the supply tank

J. Drain fuel tank, if so equipped, and reinstall drain plug

K. Cover filler vent with tape

L. Drain all oil sumps or pumps, compressors, coolers, filters and crankcase

M. Replace all plugs after draining

N. Remove intake and exhaust manifolds

O. Spray all intake and exhaust ports, including air compressor intake port, with preservative oil

(NOTE: Bar or turn engine to make sure oil goes into cylinder.)

P. Replace intake and exhaust manifolds

Q. Inspect coolant in cooling system

(NOTE: If coolant is contaminated, drain and flush; fill with rust preventative compound. Drain while hot and replace plug. Use a water soluble oil with anti-rust inhibitors obtainable from an oil company. Soluble oil requires thorough flushing of cooling system before placing in service.)

R. If air starter is used, remove exhaust plate from top of starting motor and spray with preservative oil

S. Replace exhaust plate

T. Loosen V-belt tension

U. Brush or spray a film of rust preventative compound on all exposed, unpainted surfaces of engine with a rust preventative conforming to Type P-2, Grade 1 or 2, as described in U. S. Military Specification MIL-C-16173C

JOB SHEET #2

V. Remove c[illegible]d covers and spray preservative oil over rocker levers, valve stems, springs, guides, crossheads, and push tubes

W. Replace cover

X. Cover all engine openings, including manifold exhaust and intake port, coolant inlets to cylinder head and block, oil breather and crankcase with heavy paper and duct tape

Y. Tag engine to indicate that it has been treated with preservatives and that crankshaft should not be barred over until ready to run

(NOTE: Tag should show coolant has been removed, date of treatment, and indicate that engine is not ready to run without prior removal of protective film.)

Z. Store engine in a place protected from weather and where air is dry and temperature uniform, if possible

(NOTE: Engines in storage more than 24 months should, if practical, be thoroughly flushed out with a suitable solvent or light, hot oil and then be reprocessed with rust preventative materials. Periodically inspect engines for rust or corrosion. Take corrective action if necessary.)

ENGINE STORAGE
UNIT IV

JOB SHEET #3--PREPARE A STORED ENGINE FOR SERVICE

I. Tools and materials

- A. Basic hand tool set
- B. Solvent
- C. Degreaser
- D. Mineral oil
- E. Lubricating oil
- F. Engine
- G. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Clean engine
  1. Clean off all accumulated dirt from exterior of engine
  2. Remove all paper covers, tape, and wrappings
  3. Remove rust preventative compound from unpainted surfaces of the engine, using a suitable solvent, cleaner, or degreaser
  4. Refill crankcase with clean lubricating oil
  5. Flush cooling system
- B. Inspect engine in storage less than six months
  1. Adjust injectors
  2. Adjust valves
  3. Adjust belts
  4. Check head cap screws

JOB SHEET #3

    5. Check oil filter and connections

    6. Check air filter, screens, and traps

C. Inspect engine in storage six months or more

    1. Flush entire fuel system with clean fuel oil until all preservative oil is removed

    2. Remove plug from oil header and force hot, light mineral oil through the oil passages to flush away all preservative oil and gummed oil that may have accumulated

    3. Bar over engine crankshaft three or four revolutions during flushing operation

       (NOTE: When the combustion chambers are treated, remember that total volume of combustion space is small and any excessive preservative oil may cause hydraulic lock, seriously damaging engine if it is started before all the oil is removed.)

    4. Remove all screens

    5. Check to make sure they are clean before engine is started

D. Start engine

    1. Pressurize the lubricating system including the turbocharger prior to starting the engine

    2. Start engine as described in operation and maintenance manuals

ENGINE STORAGE
UNIT IV

NAME________________________________

TEST

1. Define terms associated with engine storage.

   a. Temporary storage-- ________________________________

   b. Permanent storage-- ________________________________

2. Select true statements concerning the effects of climate on an engine in storage by placing an "X" in the appropriate blanks.

   _____a. Unpainted machine surfaces are subject to rust and corrosion

   _____b. Rate of corrosion never varies regardless of climatic condition

3. List five systems that must be protected during permanent storage.

   a. ________________________________

   b. ________________________________

   c. ________________________________

   d. ________________________________

   e. ________________________________

4. Demonstrate the ability to:

   a. Prepare an engine for temporary storage.

   b. Prepare an engine for permanent storage.

   c. Prepare a stored engine for service.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ENGINE STORAGE
UNIT IV

ANSWERS TO TEST

1. a. Temporary storage--Protection provided to an engine against rust and corrosion which will be out of service for a period of four weeks to six months
   b. Permanent storage--Protection provided to an engine against rust and corrosion which will be out of service over six months

2. a

3. a. Lubricating
   b. Cooling
   c. Fuel
   d. Crankcase
   e. External parts

4. Performance skills evaluated to the satisfaction of the instructor

ARC WELDING
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to name kinds of arc welders, select equipment used, and list safety precautions observed in arc welding. The student should also be able to demonstrate the ability to start, stop, and restart a bead, and construct a butt weld. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with arc welding with the correct definitions.
2. List safety precautions used in arc welding.
3. Name kinds of arc welders.
4. Select common equipment used in arc welding.
5. List types of electrodes.
6. Select the common sizes of electrodes used in arc welding.
7. Identify the meanings of the numbers in the electrode classification system.
8. Select purposes of electrode coating.
9. List factors to consider in selecting electrodes.
10. Differentiate between the effects of raising and lowering the arc welding current.
11. Name two methods of striking an arc.
12. Select characteristics of proper arc length.
13. Label the parts of a drawing showing the welding process.
14. Identify kinds of welds.
15. Identify types of weld joints.
16. Name the four welding positions.
17. List reasons for poor welds.

18. Demonstrate the ability to:
    - a. Start, stop, and restart a bead.
    - b. Construct a pad weld.
    - c. Construct a butt weld.
    - d. Make a pad in the vertical up position.
    - e. Make a pad in the overhead position.

ARC WELDING
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Invite welding equipment supply companies to give class presentation.

VIII. Have students list the different sizes of rods.

IX. Have students make a list of different welding supplies.

X. Give test.

(NOTE: There are several good films and filmstrips available from the various welding supply companies. See your local distributor about films and filmstrips that are available.)

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    1. TM 1--Welding Process
    2. TM 2--Kinds of Welds
    3. TM 3--Types of Weld Joints
    4. TM 4--Welding Equipment
    5. TM 5--AWS Classification of Electrodes
    6. TM 6--Methods of Striking an Arc
    7. TM 7--Welding Positions

D. Job sheets

  1. Job Sheet #1--Start, Stop, and Restart a Bead
  2. Job Sheet #2--Construct a Pad Weld
  3. Job Sheet #3--Construct a Butt Weld
  4. Job Sheet #4--Make a Pad in the Vertical Up Position
  5. Job Sheet #5--Make a Pad in the Overhead Position

E. Test

F. Answers to test

II. References:

A. Jones, M.M. *Shopwork on the Farm*. 2d ed. New York: McGraw-Hill Book Co., Inc., 1955.

B. Phipps, Lloyd J.; McColly, H.F.; Scranton, L.L.; and Cook, G.C. *Farm Mechanics Text and Handbook*. Danville, Illinois: The Interstate Printers and Publishers, Inc., 1964.

C. Kugler, Harold L. *Arc Welding Lessons for School and Farm Shop*. Cleveland, Ohio: James F. Lincoln Arc Welding Foundation, 1957.

D. Hallenberg, A.H. *How to Teach Arc Welding in Farm Mechanics*. Cleveland, Ohio: James F. Lincoln Arc Welding Foundation.

E. *Hobart Welding School Workbook*. Troy, Ohio: Hobart Brothers' Technical Center.

F. *New Lessons in Arc Welding*. Cleveland, Ohio: The Lincoln Electric Co./ James F. Lincoln Arc Welding Foundation.

G. Pierre, E.R. *Welding Processes and Power Sources*. Appleton, Wisconsin: Power Publications Co., 1968-69.

H. Jefferson, T.B. *The Welding Encyclopedia*. Morton Grove, Illinois: Monticello Books, 1968.

ARC WELDING
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Base metal--Metal to be cut or welded (Transparency 1)

B. Arc--Flow of current across a narrow gap, usually from the tip of the electrode to the base metal (Transpareny 1)

C. Fusion process--Process of heating metal to a molten state and allowing it to cool

(NOTE: The heat is produced by the electric arc in arc welding.)

D. Arc welding--Joining together of two or more pieces of metal by the fusion process

(NOTE: This is sometimes referred to as *shielded metal arc welding* or *SMAW*.)

E. Crater--Depression at the termination of a weld (Transparency 1)

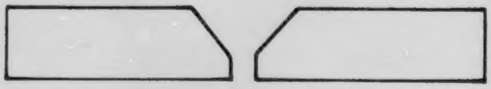
F. Pass--Single progression of a welding operation along the length of a joint or weld deposit

G. Electrode--Metal rod which conducts a current from the electrode holder to the base metal (Transparency 1)

(NOTE: The metal rod melts and deposits the metal in a bead.)

H. Bead weld--Weld made by one pass of an electrode (Transparency 2)

I. Bevel--Angular cut made on the vertical edge to allow better weld penetration



J. Butt joint--Weld between two metal joints on the same plane (Transparency 3)

K. Tack weld--Weld made to hold parts in proper alignment until the final welds are made

(NOTE: This type of welding is for assembly purposes only.)

INFORMATION SHEET

L. Puddle--That portion of a weld that is molten at the place the heat is supplied

M. AWS--American Welding Society

II. Safety precautions in arc welding

A. Do not look at the arc with the naked eye

B. Wear a head or face shield that is in good condition

C. Wear suitable clothing to protect all parts of the body

Examples: Long-sleeved shirt, leather gloves, turned-down cuffs, high top shoes or boots, buttoned-down collar

D. Do not strike an arc or weld until you are sure those in the vicinity have protective equipment or will look the other direction

(NOTE: Shout "Cover" before striking the arc.)

E. Do not weld around combustible or flammable materials

F. Use suitable tools to pick up hot metal

G. Do not weld in confined places without proper ventilation

H. Open main switch or disconnect plug when checking a welder

I. Do not leave electrode holder on welding table or in direct contact with grounded metal

J. Do not use worn or frayed cables

K. Stand on dry footing when welding

L. Keep areas around welder clean

M. Keep tools and metals in proper location

III. Kinds of arc welders

A. AC or alternating current

B. DC or direct current

C. Motor generator

(NOTE: This generator produces only DC current.)

D. Engine generator

(NOTE: The engine generator can be designed to produce AC, DC, or both types of current.)

INFORMATION SHEET

E. AC/DC transformer-rectifier

(NOTE: This welder, which is supplied by an AC power source, can be switched to produce either AC or DC welding current.)

IV. Common welding equipment (Transparency 4)

A. Welding machine

B. Electrode holder with lead

C. Ground clamp with lead

D. Shield or helmet

E. Gloves

F. Chipping hammer

G. Safety goggles or glasses

H. Wire brush

I. Electrode

V. Types of electrodes

A. Mild steel

B. High carbon steel

C. Hard surfacing

D. Low hydrogen

E. Alloy

(NOTE: Alloy electrodes are used for welding special metals such as cast iron and aluminum.)

VI. Common sizes of electrodes

(NOTE: Common sizes of electrodes range from 1/16" to 5/16".)

A. 3/32"

B. 1/8"

C. 5/32"

D. 3/16"

INFORMATION SHEET

VII. Meanings of numbers in the electrode classification system (Transparency 5)

A. E--Stands for electric arc welding

B. First two digits--Indicate tensile strength deposited in thousand pounds per square inch

C. Third digit--Indicates welding position

1. "1" indicates all positions

2. "2" indicates flat and horizontal only

3. "3" indicates flat only

D. Fourth or last digit--Represents special characteristics and usability of the electrode

Example:

Last-Digit Characteristics

Last Digit	Power Supply	Arc Action	Type of Flux	Penetration Characteristics
0	10, DC+; 20, AC; or DC	Digging	10, organic; 20, mineral	10, deep 20, medium
1	AC or DC+	Digging	Organic	Deep
2	AC or DC	Medium	Ductile	Medium
3	AC or DC	Soft	Ductile	Light
4	AC or DC	Soft	Ductile	Light
5	DC+	Medium	Low hydrogen	Medium
6	AC or DC+	Medium	Low hydrogen	Medium
7	AC or DC	Soft	Mineral	Medium
8	AC or DC+	Medium	Low hydrogen	Medium

(Reprinted by permission from T. B. Jefferson, The Welding Encyclopedia, p. E-4, Monticello Books, Morton Grove, Illinois, 1968.)

VIII. Purposes of electrode coating

A. Stabilize the arc

B. Shield molten puddle from air

C. Float impurities out of puddle

D. Form slag and slow cooling

E. Increase speed

F. Improve quality of weld

INFORMATION SHEET

IX. Factors to consider in selecting electrodes

- A. Base metal strength properties
- B. Base metal composition
- C. Welding position
- D. Welding current
- E. Joint design and fit-up
- F. Thickness and shape of base metal
- G. Production efficiency and job conditions

X. Effects of raising and lowering arc welding current

- A. Raising the current produces more heat
- B. Lowering the current produces less heat

XI. Methods of striking an arc (Transparency 6)

- A. Scratching

  (NOTE: This method is similar to striking a match.)

- B. Tapping

XII. Characteristics of proper arc length

- A. End of electrode is the same distance from the base metal as diameter of electrode

  Example: For a 1/8" electrode the arc length should be 1/8"

- B. Correct arc length makes a steady hum of the welder and a "frying" sound at the arc

XIII. Parts of the welding process (Transparency 1)

- A. Electrode
- B. Wire core
- C. Coating (flux)
- D. Arc

INFORMATION SHEET

- E. Gaseous shield
- F. Weld
- G. Slag
- H. Heat lines
- I. Base metal
- J. Penetration
- K. Crater
- L. 15° - 30° angle of electrode
- M. Direction of travel

XIV. Kinds of welds (Transparency 2)

- A. Fillet
- B. Groove
- C. Bead

XV. Types of weld joints (Transparency 3)

- A. Edge
- B. Butt
- C. Corner
- D. T
- E. Lap

XVI. Welding positions (Transparency 7)

- A. Flat
- B. Horizontal
- C. Vertical

  (NOTE: The bead may be started either from the top or the bottom depending on the characteristics of the metal.)
- D. Overhead

INFORMATION SHEET

XVII. Reasons for poor welds

A. Machine adjustment too hot or too cool

B. Electrode size too large or too small

C. Improper movement of electrode

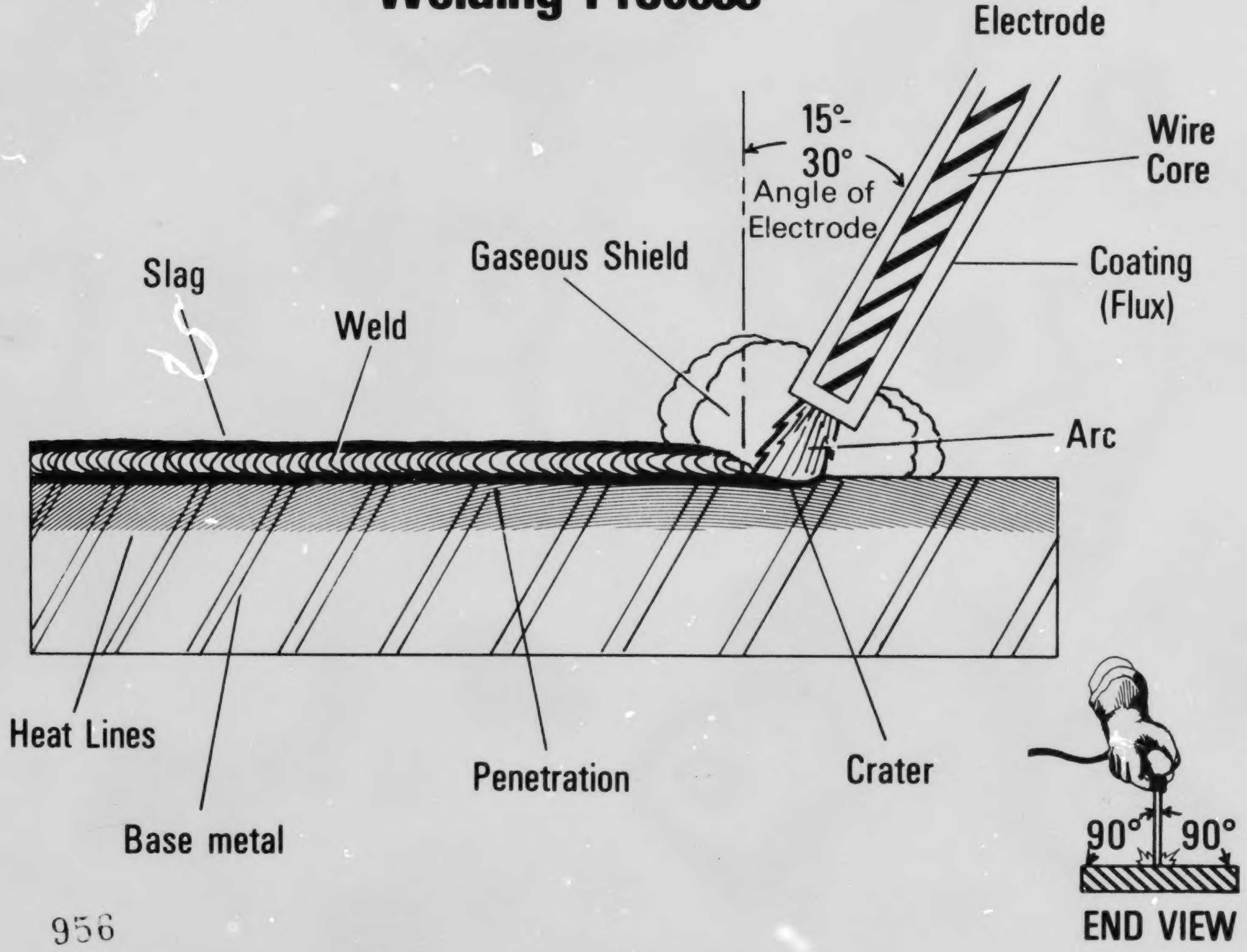
D. Improper angle of electrode

E. Improper base metal preparation

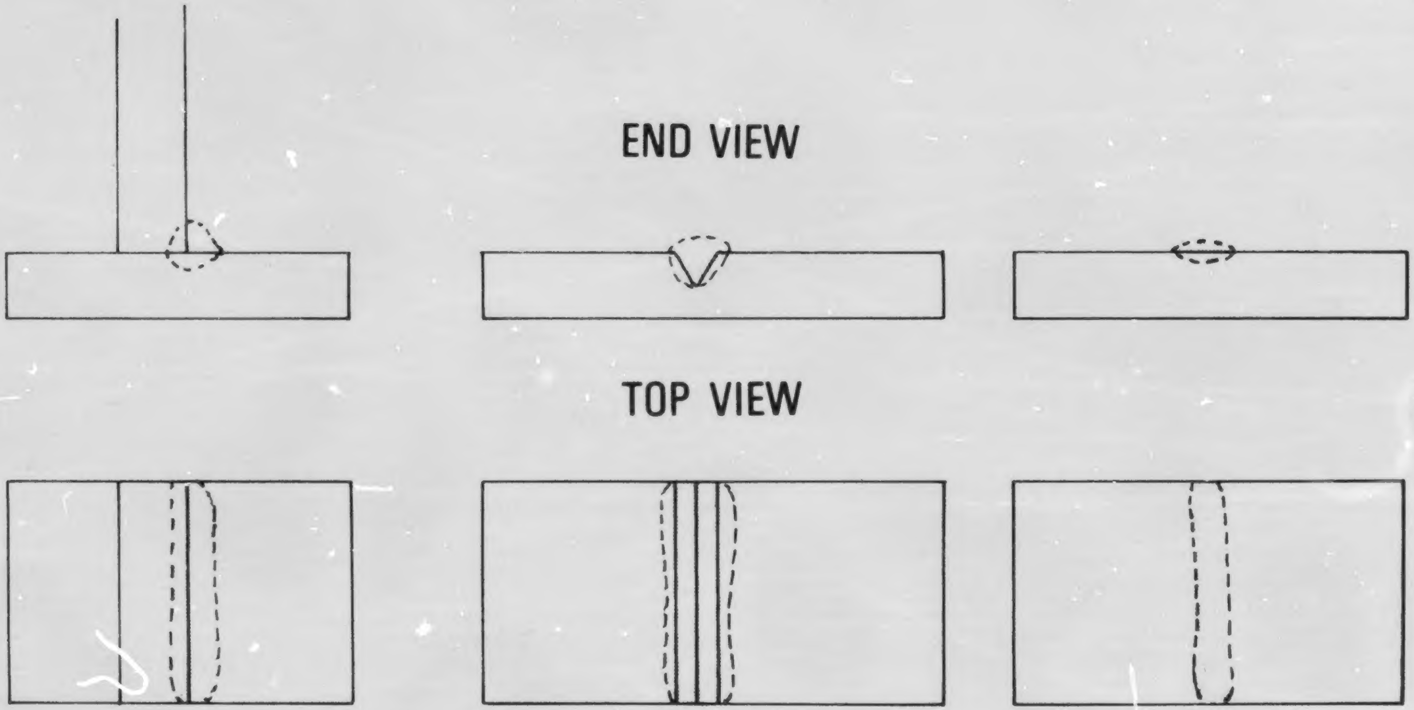
(NOTE: Base metal should be clean and free from oil and rust.)

F. Arc length too long or too short

Welding Process


Electrode
15°-30°
Angle of Electrode
Wire Core
Coating (Flux)
Gaseous Shield
Slag
Weld
Arc
Heat Lines
Base metal
Penetration
Crater
90°
90°
END VIEW

Kinds of Welds



Fillet Weld

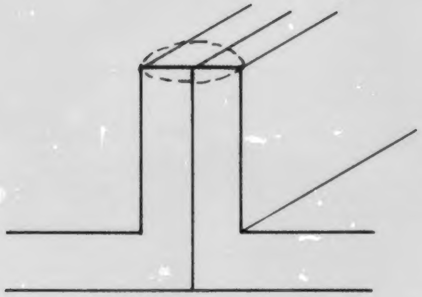
Groove Weld

Bead Weld

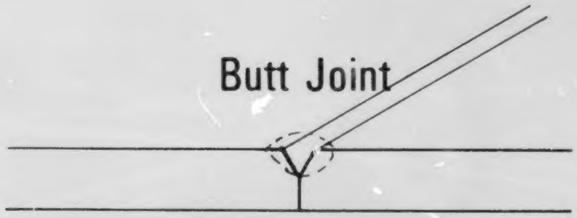
END VIEW

TOP VIEW

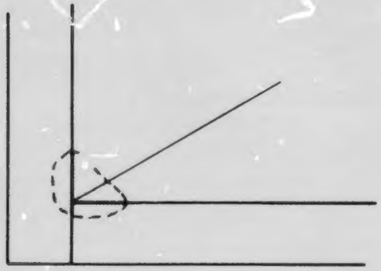
Types of Weld Joints



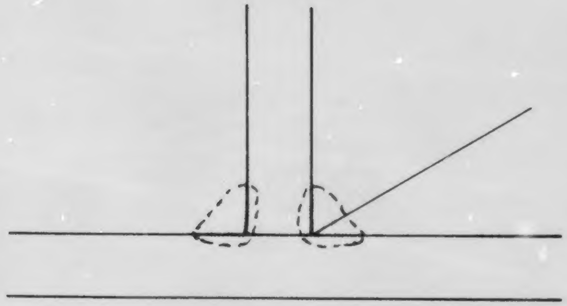
Edge Joint



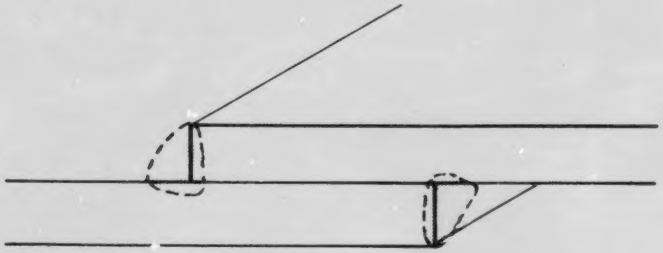
Butt Joint



Corner Joint

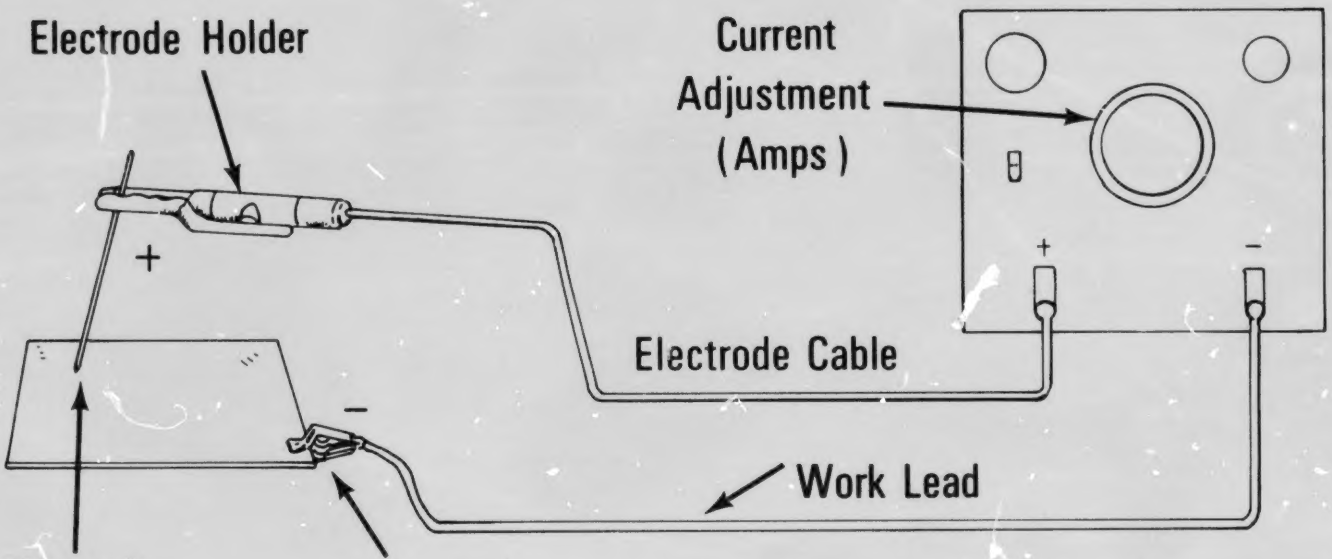


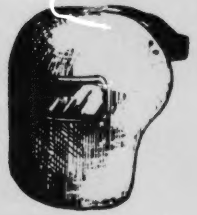
T Joint

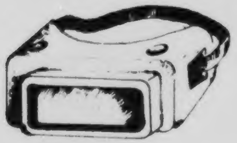


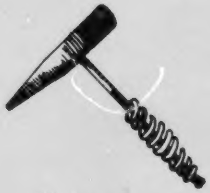
Lap Joint

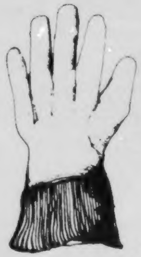
Welding Equipment

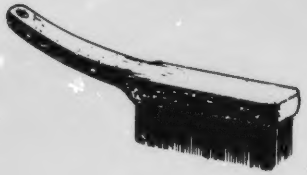

Welding Machine
Electrode Holder
Current
Adjustment
(Amps)
+
+
−
Electrode Cable
−
Work Lead
Electrode
Ground Clamp


Shield or Helmet


Safety Goggles


Chipping Hammer


Gloves


Wire Brush

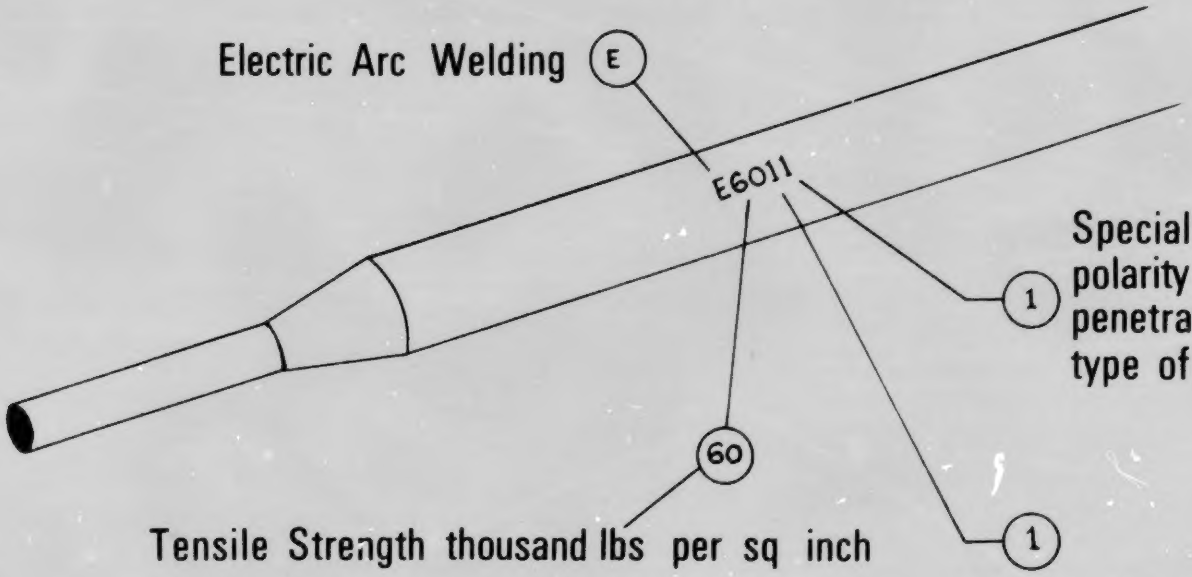
TM 4

962

963

D:F - 19-F

AWS Classification of Electrodes



Electric Arc Welding

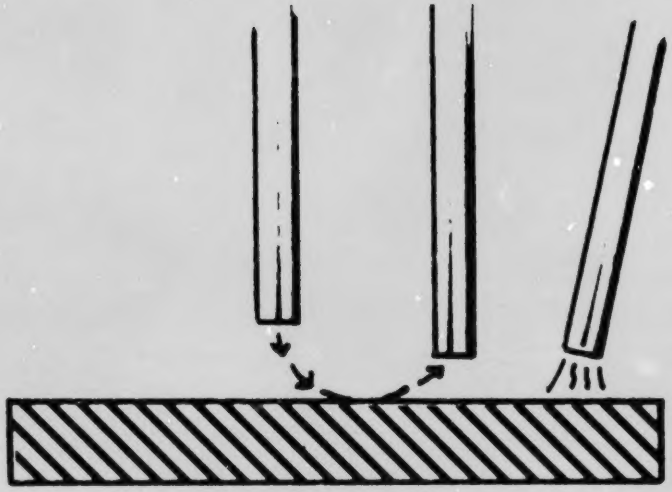
Special char.
polarity
penetration
type of welder

Tensile Strength thousand lbs per sq inch

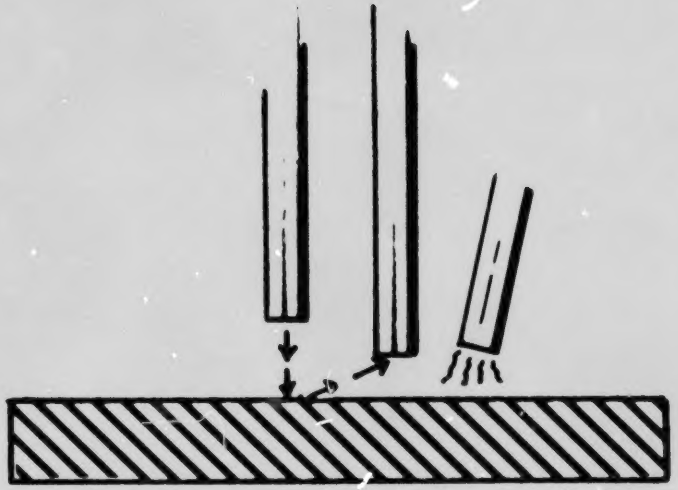
Welding Position
1. all positions
2. flat and horizontal
3. flat

E6011 MILD STEEL ELECTRODE

Methods of Striking an Arc

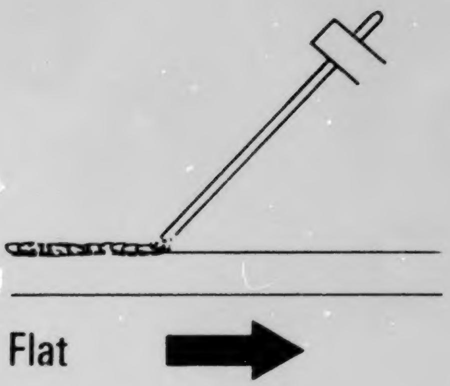


Scratching

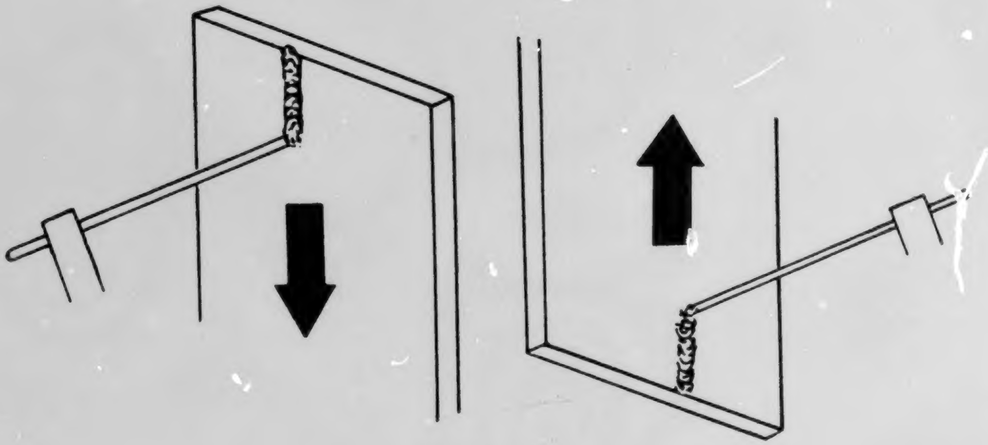


Tapping

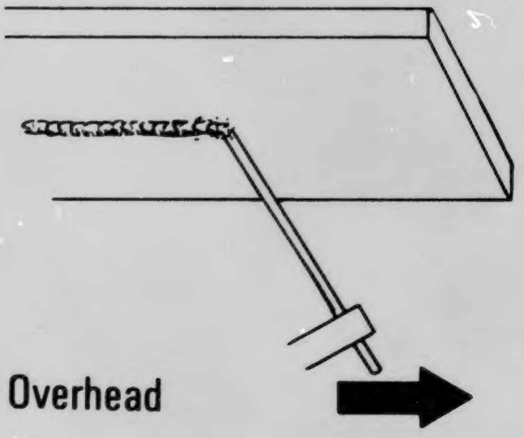
Welding Positions



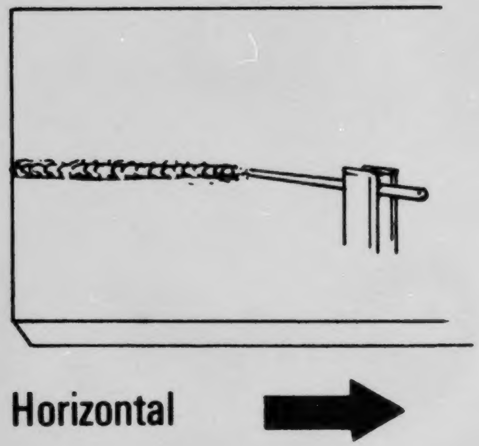
Flat



Vertical



Overhead



Horizontal

TM 7

968

969

D:F - 25-F

ARC WELDING
UNIT I

JOB SHEET #1--START, STOP, AND RESTART A BEAD

I. Tools and materials

- A. Piece of metal 1/4" to 3/8" thick, 4" x 4"
- B. Welder
- C. Electrode holder with lead
- D. Ground clamp with lead
- E. Helmet
- F. Gloves
- G. Electrodes
- H. Safety goggles
- I. Chipping hammer
- J. Wire brush

II. Procedure

(CAUTION: Follow all shop safety procedures.)

- A. Prepare metal for welding

  (NOTE: Metal should be clean and free of oil and rust.)

- B. Strike arc 1" from edge where bead is to begin (Figures 1 and 2)

FIGURE 1

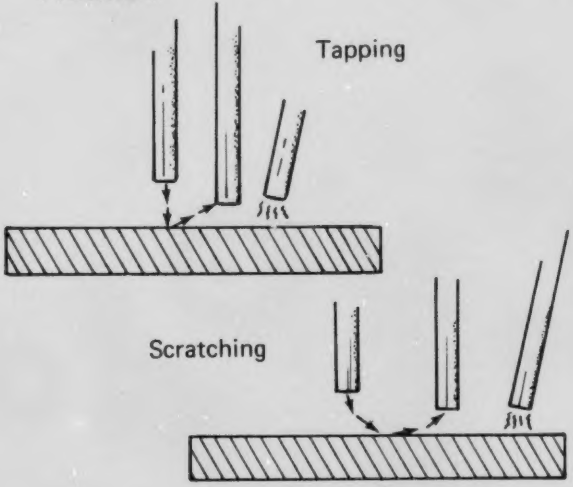
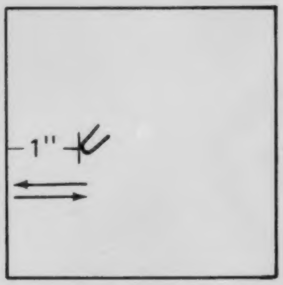


FIGURE 2

To Start



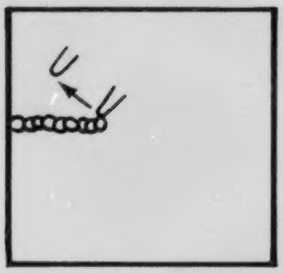
JOB SHEET #1

C. Move to edge when arc burns brightly, maintaining the correct arc length; begin forming the puddle

D. Move across metal two inches

E. Move electrode back through the puddle and lift up to stop bead (Figure 3)

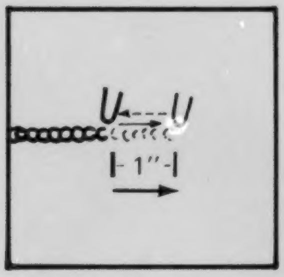
FIGURE 3



(NOTE: This will prevent cracks from forming in the puddle.)

F. Strike arc about 1" in front of crater to restart (Figure 4)

FIGURE 4



G. Move back through the crater when arc burns brightly and then resume the bead

(NOTE: This is necessary in order for beads to blend with one another without a change in continuity.)

ARC WELDING
UNIT I

JOB SHEET #2--CONSTRUCT A PAD WELD

I. Tools and materials

   A. Piece of metal 1/4" to 3/8" thick, 4" x 4"

   B. Welder

   C. Electrode holder with lead

   D. Ground clamp with lead

   E. Helmet

   F. Gloves

   G. Electrodes

   H. Safety goggles

   I. Chipping hammer

   J. Wire brush

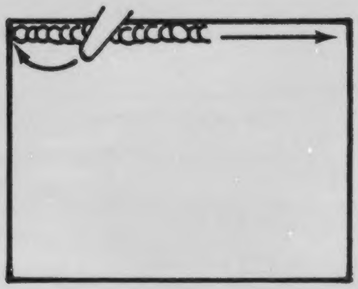
II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Prepare metal for welding

   B. Strike arc and move to point to begin pad (Figure 1)

FIGURE 1



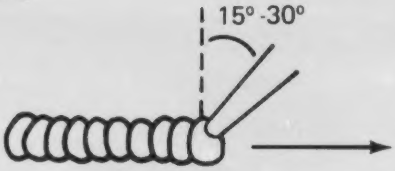
   C. Lay a straight bead across the plate using a weaving motion

   (NOTE: When using an E6011 electrode, it is necessary to use some type of rod manipulation in running a bead.)

JOB SHEET #2

D. Hold electrode at a 15° to 30° angle in direction of travel and lower electrode as rod burns away to maintain correct arc length (Figure 2)

FIGURE 2

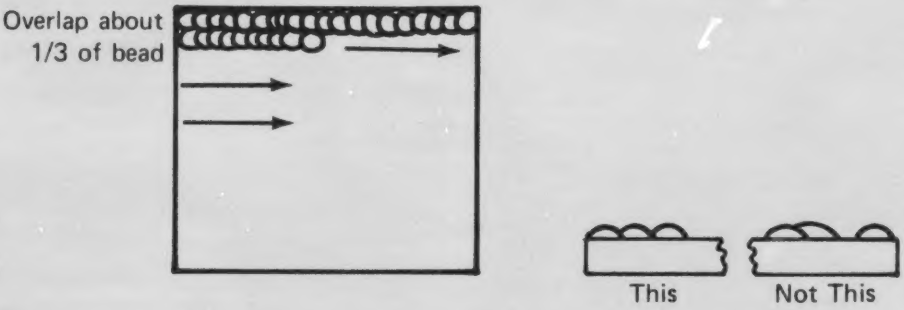


E. Move electrode steadily from right to left across pad

F. Clean the slag from each bead before starting the next one

G. Run beads until pad is full, overlapping each bead (Figure 3)

FIGURE 3



H. Let each bead cool until slag is black before chipping

I. Run additional layers until desired thickness is obtained

ARC WELDING
UNIT I

JOB SHEET #3--CONSTRUCT A BUTT WELD

I. Tools and materials

- A. Pieces of metal 1/4" to 3/8" thick, 3" x 6" (2)
- B. Welder
- C. Electrode holder with leads
- D. Ground clamp with leads
- E. Helmet
- F. Gloves
- G. Electrodes
- H. Safety goggles
- I. Chipping hammer
- J. Wire brush

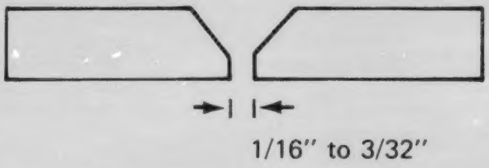
II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Prepare metal to be welded (Figure 1)

(NOTE: If metal thickness is over 1/8", the edges should be beveled.)

FIGURE 1



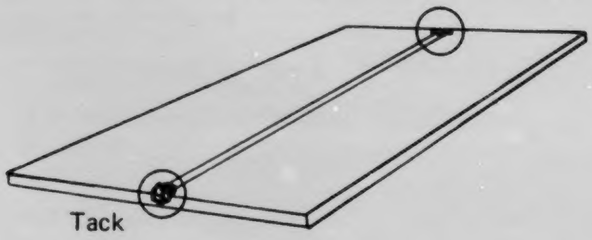
B. Place two pieces of metal parallel to each other

(NOTE: Leave a space from 1/16" to 3/32" between them. See Figure 1.)

JOB SHEET #3

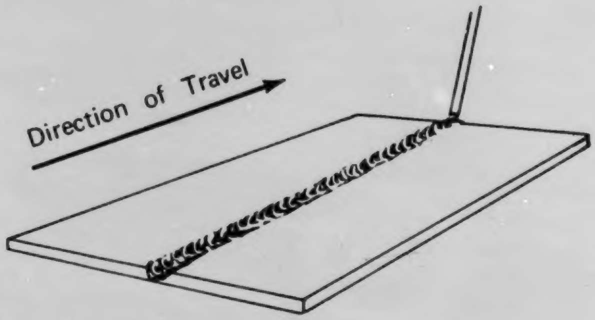
C. Tack weld pieces together at both ends (Figure 2)

FIGURE 2



D. Complete weld using a single pass (Figure 3)

FIGURE 3


Direction of Travel

E. Chip slag and brush weld

ARC WELDING
UNIT I

JOB SHEET #4--MAKE A PAD IN THE VERTICAL UP POSITION

I. Tools and materials

  A. Arc welding station and required tools

  B. Mild steel plates 3/8" thick, 6" by 6"

  C. Electrodes E-6010 1/8" or 5/32"

    1. 1/8" - 75-130 amps

    2. 5/32" - 90-175 amps

  D. Current Direct Current Reverse Polarity + at 1/8" electrode 75-130 amps

  E. Protective clothing

  F. Safety goggles

II. Procedure

(CAUTION: Follow all shop safety procedures.)

  A. Adjust machine to correct type and amount of current

  B. Prepare and tack metal in a vertical position

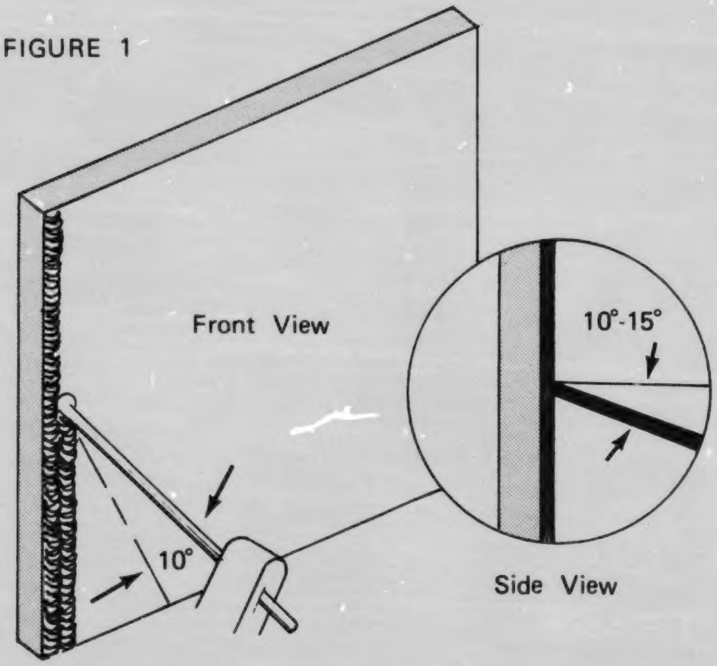
  (NOTE: Vertical up welding has deeper penetration than the vertical down; this technique is usually reserved for thicker metals and requires lower amperage settings.)

  C. Position electrode at 90° angle to plate and tip down from horizontal 10-15° for first bead

JOB SHEET #4

D. All other beads require a 10° side angle with each previously laid bead with the 10-15° angle down from horizontal remaining the same (Figure 1)

FIGURE 1



E. Strike an arc on the lower left hand corner of plate, hold high arc length 1 to 2 seconds and start welding upward to top of plate

(NOTE: A slight manipulation of the rod tip will be necessary.)

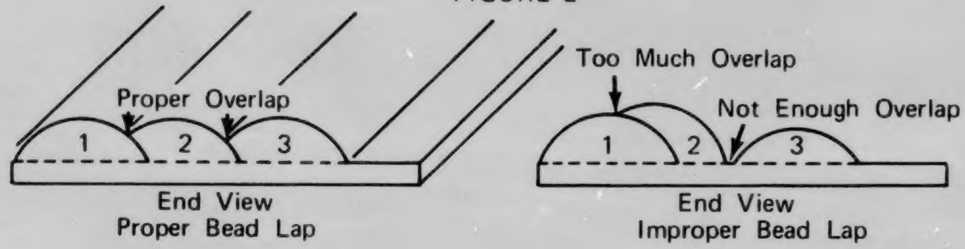
F. After laying first bead, chip and brush weld clean, and check surface for porosity and slag inclusions

(NOTE: Crater at end of each pass should be filled.)

JOB SHEET #4

G. Deposit additional beads overlapping each at least 1/3 until pad is filled (Figure 2)

FIGURE 2


Proper Overlap
1
2
3
End View
Proper Bead Lap
Too Much Overlap
Not Enough Overlap
1
2
3
End View
Improper Bead Lap

H. After a complete layer of passes has been applied, clean thoroughly and turn in to instructor for evaluation

ARC WELDING
UNIT I

JOB SHEET #5--MAKE A PAD IN THE OVERHEAD POSITION

I. Tools and materials

- A. Arc welding station and required tools
- B. Mild steel plate 1/4" or 3/8", two pieces 6" x 6"
- C. Electrode E-6010 1/8" or 5/32"
    - 1. 1/8" - 75-130 amps
    - 2. 5/32" - 90-175 amps
- D. Protective clothing
- E. Safety goggles

II. Procedure

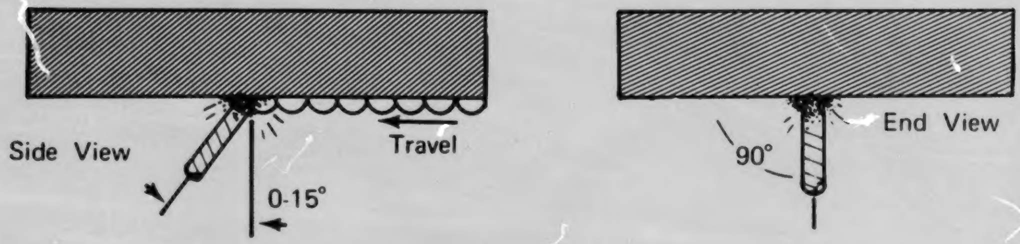
(CAUTION: Follow all shop safety procedures.)

- A. Adjust welding machine to correct current and amperage setting
- B. Prepare and tack metal in the overhead position

    (NOTE: Metal will be in horizontal position with floor.)
- C. Strike arc at edge of plate; hold a high arc for one or two seconds to heat up base metal

    (CAUTION: Avoid depositing first bead too close to edge of plate.)
- D. Move electrode along plate with a slight angle in the direction of travel (Figure 1)

FIGURE 1 Overhead Welding



JOB SHEET #5

(NOTE: Metal should be deposited with a very short arc. A slight whipping motion may be helpful in controlling bead shape.)

E. Start at the end of plate and progress across plate

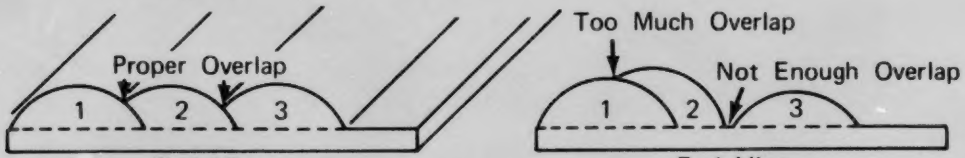
(NOTE: After completion of each bead thoroughly chip and brush the weld checking for bead appearance which will determine if current, amps, or welding technique needs to be changed.)

F. Deposit additional beads until plate is completely covered

(NOTE: Each additional bead should be overlapped about 1/3 of previous bead. Bead should have a smooth surface without noticeable "valleys" or "trapped slag.") (Figure 2)

(NOTE: Alternate travel direction for each pass.)

FIGURE 2



End View
Proper Bead Lap

End View
Improper Bead Lap

G. After completing the required layer of passes, clean pad and turn in for instructor's approval

ARC WELDING
UNIT I

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Metal to be cut or welded

______b. Weld made by one pass of an electrode

______c. Metal rod which conducts a current from the electrode holder to the base metal

______d. Joining together of two or more pieces of metal by the fusion process

______e. Depression at the termination of a weld

______f. Angular cut made on the vertical edge to allow better weld penetration

______g. That portion of a weld that is molten at the place the heat is supplied

______h. Process of heating metal to a molten state and allowing it to cool

______i. Single progression of a welding operation along the length of a joint or weld deposit

______j. Weld between two metal joints on the same plane

______k. American Welding Society

______l. Flow of current across a narrow gap, usually from the tip of the electrode to the base metal

______m. Weld made to hold parts in proper alignment until the final welds are made

1. Arc welding
2. Fusion process
3. Arc
4. Base metal
5. Crater
6. Pass
7. Bead weld
8. Bevel
9. Butt joint
10. Tack weld
11. Electrode
12. Puddle
13. AWS

2. List five safety precautions used in arc welding.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

3. Name two kinds of arc welders.

a. ______________________________

b. ______________________________

4. Select common equipment used in arc welding by placing an "X" in the appropriate blanks.

_____a. Welding machine

_____b. Electrode

_____c. Gloves

_____d. Wire brush

_____e. Cart

_____f. Shield or helmet

_____g. Chipping hammer

_____h. Ball peen hammer

_____i. Safety goggles or glasses

_____j. Hacksaw

_____k. Screwdriver

5. List three types of electrodes.

a. ______________________________

b. ______________________________

c. ______________________________

6. Select the common sizes of electrodes used in arc welding by placing an "X" in the appropriate blanks.

_____a. 1/16"

_____b. 1/8"

_____c. 3/32"

_____d. 5/15"

_____e. 5/32"

_____f. 3/16"

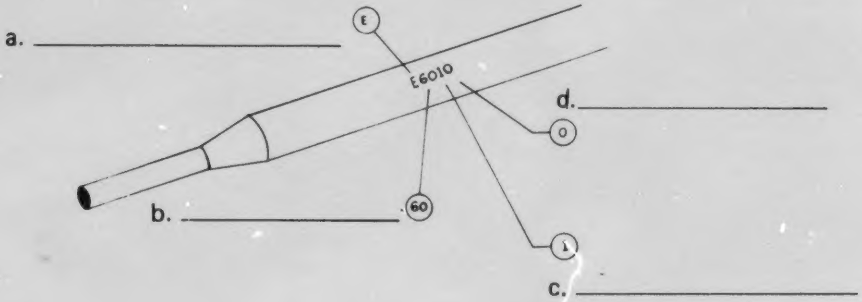
_____g. 3/8"

_____h. 3/64"

_____i. 3/4"

_____j. 1/2"

7. Identify the meanings of the numbers in the electrode classification system.



8. Select purposes of electrode coating by placing an "X" in the appropriate blanks.

______a. Increase speed

______b. Stabilize the arc

______c. Protect the welder from shock

______d. Shield molten puddle from air

______e. Keep electrode from shorting out

______f. Form slag and slow cooling

______g. Tack metal to be welded

______h. Float impurities out of puddle

______i. Improve quality of weld

9. List four factors to consider in selecting electrodes.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

10. Differentiate between the effects of raising and lowering the arc welding current by placing an "X" next to the effect of lowering the arc welding current.

______a. Produces more heat

______b. Produces less heat

11. Name two methods of striking an arc.

    a. ____________________

    b. ____________________

12. Select characteristics of proper arc length by placing an "X" in the blanks.

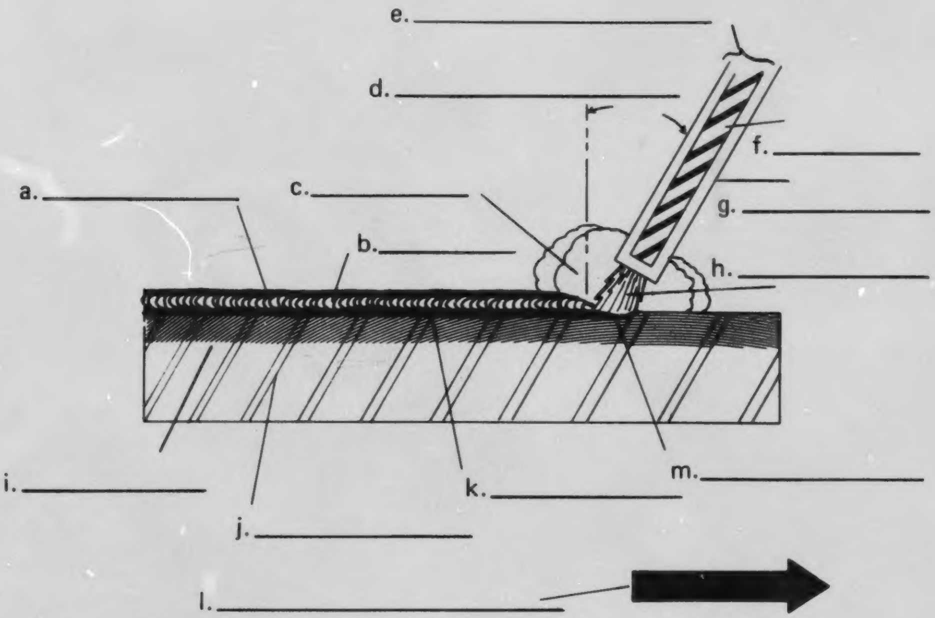
    _____a. Arc length is 1/2" long

    _____b. Arc length is the same as the length of the electrode

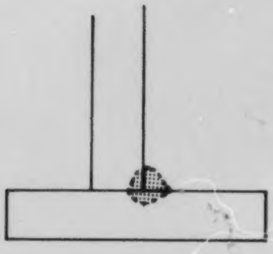
    _____c. End of electrode is the same distance from the base metal as diameter of electrode

    _____d. Correct arc length makes a steady hum of the welder and a "frying" sound at the arc

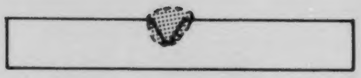
13. Label the parts of the welding process in the drawing below by writing the correct names in the blanks.



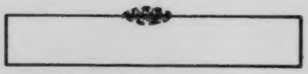
14. Identify the following welds.



a. ______________________

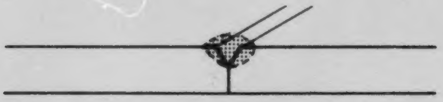


b. ______________________

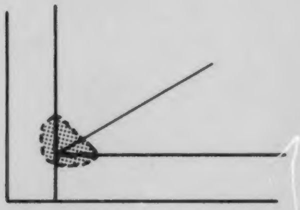


c. ______________________

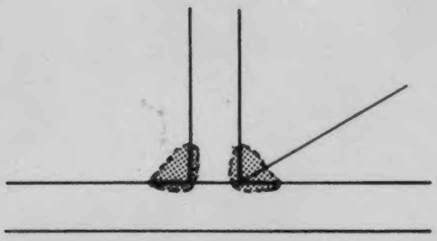
15. Identify the following weld joints.



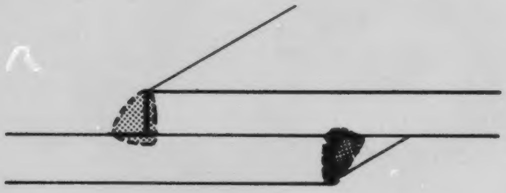
a. ______________________



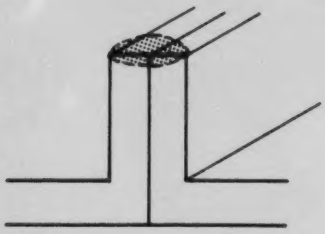
b. ______________________



c. ______________________



d. ______________________



e. ______________________

16. Name the four welding positions.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

17. List four reasons for poor welds.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

18. Demonstrate the ability to:

    a. Start, stop, and restart a bead.

    b. Construct a pad weld.

    c. Construct a butt weld.

    d. Make a pad in the vertical up position.

    e. Make a pad in the overhead position.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ARC WELDING
UNIT I

ANSWERS TO TEST

1. a. 4
   b. 7
   c. 11
   d. 1
   e. 5
   f. 8
   g. 12
   h. 2
   i. 6
   j. 9
   k. 13
   l. 3
   m. 10

2. Any five of the following:

   a. Do not look at the arc with the naked eye
   b. Wear a head or face shield that is in good condition
   c. Wear suitable clothing to protect all parts of the body
   d. Do not strike an arc or weld until you are sure those in the vicinity have protective equipment or will look the other direction
   e. Do not weld around combustible or flammable materials
   f. Use suitable tools to pick up hot metal
   g. Do not weld in confined places without proper ventilation
   h. Open main switch or disconnect plug when checking a welder
   i. Do not leave electrode holder on welding table or in direct contact with grounded metal
   j. Do not use worn or frayed cables
   k. Stand on dry footing when welding
   l. Keep areas around welder clean
   m. Keep tools and metals in proper location

3. Any two of the following:

   a. AC or alternating current
   b. DC or direct current
   c. Motor generator
   d. Engine generator
   e. AC/DC transformer-rectifier

4. a, b, c, d, f, g, i

5. Any three of the following:

   a. Mild steel
   b. High carbon steel
   c. Hard surfacing
   d. Low hydrogen
   e. Alloy

6. b, c, e, f

7. a. E--Electric arc welding
   b. 60--Tensile strength deposited in thousand pounds per square inch
   c. 1--Welding position; all positions
   d. 0--Special characteristics and usability of electrode

8. a, b, d, f, h, i

9. Any four of the following:

   a. Base metal strength properties
   b. Base metal composition
   c. Welding position
   d. Welding current
   e. Joint design and fit-up
   f. Thickness and shape of base metal
   g. Production efficiency and job conditions

10. b

11. a. Scratching
    b. Tapping

12. c, d

13. a. Slag
    b. Weld
    c. Gaseous shield
    d. 15° - 30° angle of electrode
    e. Electrode
    f. Wire core
    g. Coating (flux)
    h. Arc
    i. Heat lines
    j. Base metal
    k. Penetration
    l. Direction of travel
    m. Crater

14. a. Fillet
    b. Groove
    c. Bead

15. a. Butt
    b. Corner
    c. T
    d. Lap
    e. Edge

16. a. Flat
    b. Horizontal
    c. Vertical
    d. Overhead

17. Any four of the following:

    a. Machine adjustment too hot or too cool
    b. Electrode size too large or too small
    c. Improper movement of electrode
    d. Improper angle of electrode
    e. Improper base metal preparation
    f. Arc length too long or too short

18. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE CUTTING
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to set up, light, adjust, and turn off an oxyacetylene cutting outfit following the proper order and safety precautions. The student should also be able to make ninety-degree cuts on mild steel and cut round stock. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with oxyacetylene cutting with the correct definitions.
2. Identify the parts of an oxyacetylene cutting outfit.
3. Identify the parts of a torch body and cutting attachment.
4. List rules for the safe handling of oxygen and acetylene equipment.
5. Identify the types of oxyacetylene cutting flames.
6. List reasons for poor cuts.
7. Select causes of a backfire.
8. Arrange in order the steps involved when a backfire occurs.
9. Select true statements concerning what happens when a flashback occurs.
10. List in the proper order the steps to follow in case of a flashback.
11. Demonstrate the ability to:
    a. Set up equipment for oxyacetylene cutting.
    b. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment.
    c. Make ninety-degree cuts on mild steel and restart a cut.
    d. Cut round stock.

OXYACETYLENE CUTTING
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Secure color flame charts showing types of flames from welding supplier.

VIII. Obtain film from local welding supplier to show various techniques in cutting.

IX. Have students list the different size cutting tips.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    1. TM 1--Oxyacetylene Cutting Outfit
    2. TM 2--Parts of a Torch Body and Cutting Attachment
    3. TM 3--Types of Oxyacetylene Cutting Flames
- D. Job sheets
    1. Job Sheet #1--Set Up Equipment for Oxyacetylene Cutting
    2. Job Sheet #2--Turn On, Light, Adjust to a Neutral Flame, and Turn Off Oxyacetylene Cutting Equipment.
    3. Job Sheet #3--Make Ninety-Degree Cuts on Mild Steel and Restart a Cut
    4. Job Sheet #4--Cut Round Stock

E. Test

F. Answers to test

II. References:

A. Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A. *Modern Welding*. Homewood, Illinois: The Goodheart-Willcox Co., 1970.

B. Phipps, Lloyd J.; McColly, H.F.; Scranton, L. L.; and Cook, G.C. *Farm Mechanics Text and Handbook*. Danville, Illinois: Interstate Printers and Publishers, Inc., 1964.

C. *Smith's Short Course for Gas Cutting, Welding, Brazing*. Minneapolis, Minnesota: Division of Tescom Corp./Education Department of Smith Welding Equipment.

D. *The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures*. New York: Linde Div./Union Carbide Corp.

OXYACETYLENE CUTTING
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Flashback--Fire inside of the torch

(CAUTION: This is a very dangerous condition.)

B. Backfire--Momentary burning back of the flame into the tip

C. Flame cutting--Process by which iron or steel is heated to a temperature where it can be rapidly oxidized by high purity oxygen flowing under pressure through a cutting torch

(NOTE: As the metal is oxidized, the preheat flame maintains the temperature necessary to keep the oxidation process going in a narrow zone across the length of the base metal.)

D. Slag box--Metal container with a layer of water or sand to catch hot slag

E. Slag--Metal which melts away during the oxyacetylene cutting process

F. Dragline--Situation in which the most distant portion of the cutting stream lags behind the stream nearest the cutting tip

G. Kerf--Area of material removed from a piece of metal by a saw or cutting torch

H. Oxide--Substance that is produced when oxygen is combined with an element

Examples: Rust, corrosion, coating, film, or scale

I. Oxidizing--Combining oxygen with another substance

Example: A metal is oxidized when the metal is cut

J. Purge--To remove any foreign material from a system or component by flushing with the gas used in that system

II. Parts of an oxyacetylene cutting outfit (Transparency 1)

A. Oxygen cylinder

B. Oxygen regulator

INFORMATION SHEET

C. Oxygen pressure regulating screw

D. Oxygen cylinder valve

E. Acetylene cylinder

F. Acetylene regulator

G. Acetylene pressure regulating screw

H. Acetylene cylinder valve

I. Safety chain

J. Cylinder truck

K. Oxygen hose

(NOTE: The color code for oxygen is green.)

L. Acetylene hose

(NOTE: The color code for acetylene is red.)

M. Oxygen fitting

(NOTE: The oxygen fitting has right-hand threads.)

N. Acetylene fitting

(NOTE: The acetylene fitting has left-hand threads with a grooved nut.)

O. Oxygen torch valve

P. Torch body

Q. Acetylene torch valve

R. Cutting attachment

S. Oxygen preheat valve

T. Oxygen cutting lever

U. Tip

V. Tip nut

INFORMATION SHEET

III. Parts of the torch body and cutting attachment (Transparency 2)

  A. Cutting torch

    1. Oxygen fitting
    2. Acetylene fitting
    3. Oxygen torch valve
    4. Acetylene torch valve
    5. Torch body
    6. Oxygen cutting lever
    7. Oxygen preheat valve
    8. Tip nut
    9. Tip

  B. Cutting tip

  (NOTE: The selection of the correct tip for the job is determined by the thickness of metal, the size of tip orifice, and the oxygen cutting pressures. See manufacturer's recommendations.)

    1. Preheat orifice

    (NOTE: The preheat orifice heats metal to kindling point of approximately 1600° F 755° C .)

    2. Cutting orifice

    (NOTE: The cutting orifice removes oxidized metal.)

IV. Rules for safe handling of oxygen and acetylene equipment

  A. Secure cylinders in an upright position to prevent damage to valves or regulators

  B. Purge cylinder valve before attaching regulators

  C. Release adjusting screws on regulator before opening cylinder valve

  D. Stand to one side of regulator while slowly opening the cylinder valve

INFORMATION SHEET

E. Do not use acetylene at pressures higher than 15 psi

(NOTE: Acetylene becomes unstable at pressures higher than 15 psi and becomes highly explosive.)

F. Purge oxygen and acetylene passages before lighting torch

G. Light acetylene gas before opening oxygen valve on torch

H. Do not use oil on regulators, torches, fittings, or any place that it may come in contact with oxygen

(NOTE: Oil or grease and oxygen have a very great attraction for one another and will unite with explosive violence.)

I. Do not use oxygen as a substitute for compressed air

J. Keep heat, flames, and sparks away from combustibles

K. Use safety goggles, gloves, and protective clothing

(NOTE: Keep gloves, hands, and clothing free from oil and grease.)

L. Test connections for leaks with soapsuds and paintbrush

M. Do not weld on containers that have been used for combustible materials

N. Avoid breathing toxic fumes when welding

Example: Galvanized metal

O. Do not leave a burning torch unattended

P. Do not cut or weld near concrete

Q. Operate torch in a well-ventilated place

R. Weld or cut at least five feet from cylinders

S. Protect hoses from hot metal, rupture, or mechanical damage

V. Types of oxyacetylene cutting flames (Transparency 3)

A. Carburizing flame

(NOTE: The flame has an excess of acetylene gas.)

INFORMATION SHEET

B. Neutral flame

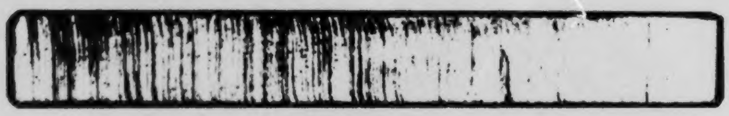
(NOTE: The flame has the proper ratio of oxygen to acetylene.)

C. Oxidizing flame

(NOTE: There is an excess of oxygen.)

VI. Reasons for poor cuts

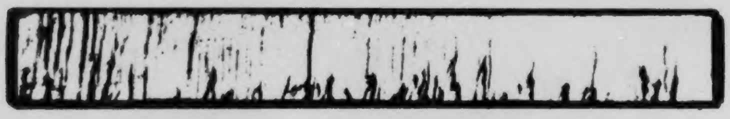
Example:



(NOTE: This is a correctly made cut in one-inch plate. The edge is square and the draglines are essentially vertical and not too pronounced.)

A. Preheat flames too small

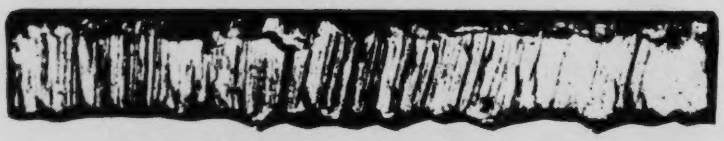
Example:



(NOTE: The cutting speed was too slow, causing bad gouging at the bottom.)

B. Preheat flames too long

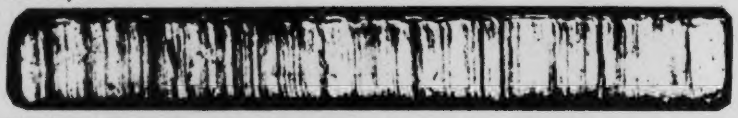
Example:



(NOTE: The top surface has melted over, the cut edge is irregular, and there is an excessive amount of adhering slag.)

C. Oxygen pressure too low

Example:

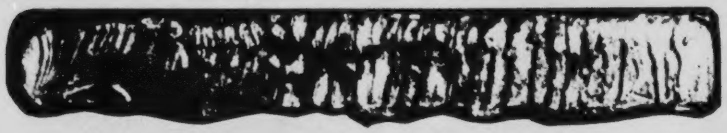


(NOTE: The top edge has melted over because the cutting speed was too slow.)

INFORMATION SHEET

D. Oxygen pressure too high; nozzle size too small

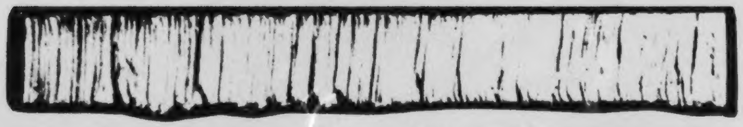
Example:



(NOTE: The entire control of the cut has been lost.)

E. Cutting speed too slow

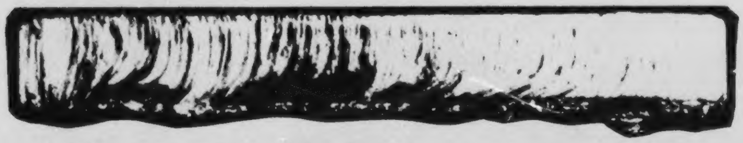
Example:



(NOTE: The irregularities of the draglines are emphasized.)

F. Cutting speed too fast

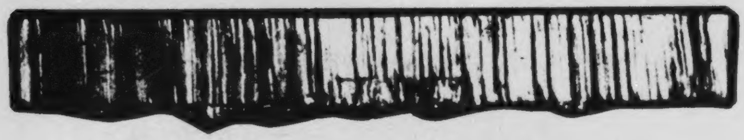
Example:



(NOTE: There is a pronounced break to the dragline and the cut edge is irregular.)

G. Blowpipe travel unsteady

Example:

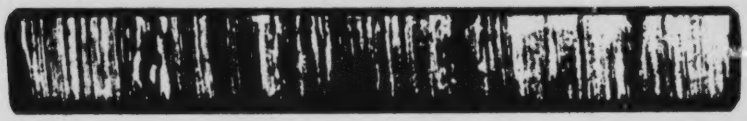


(NOTE: The cut edge is wavy and irregular.)

INFORMATION SHEET

H. Cut lost and not carefully restarted

Example:



(NOTE: Bad gouges were caused at the restarting point.)

VII. Causes of a backfire

A. Insufficient acetylene or oxygen pressure

B. Loose cutting tip

C. Dirty tip

D. Overheating of cutting tip

E. Bad "O" ring in torch body

(NOTE: The above causes should be carefully checked to avoid backfire.)

VIII. Steps involved when a backfire occurs

A. Flame burns momentarily back into tip

B. A loud snap or pop is emitted from the torch

C. Flame either goes out or continues to burn in normal manner

IX. What happens when a flashback occurs

A. Flame disappears inside the torch body

B. Squealing noise, smoke, and/or sparks are emitted from the torch tip

X. Steps to follow in case of a flashback

A. Close oxygen preheat valve

B. Close oxygen torch valve

C. Close acetylene torch valve

D. Release oxygen regulator screw

INFORMATION SHEET

E. Release acetylene regulator screw

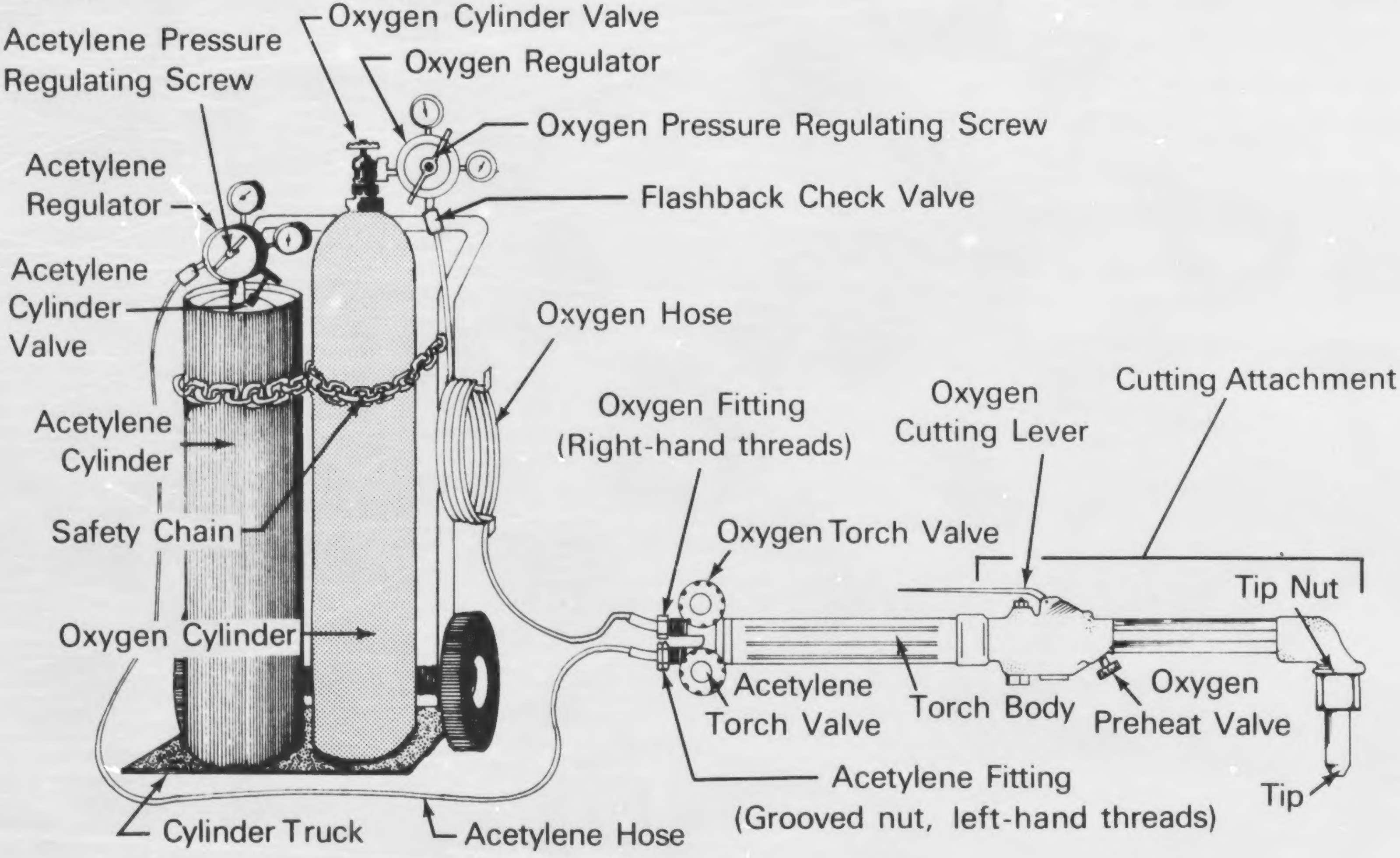
F. Examine acetylene unit

G. Reset regulator pressures

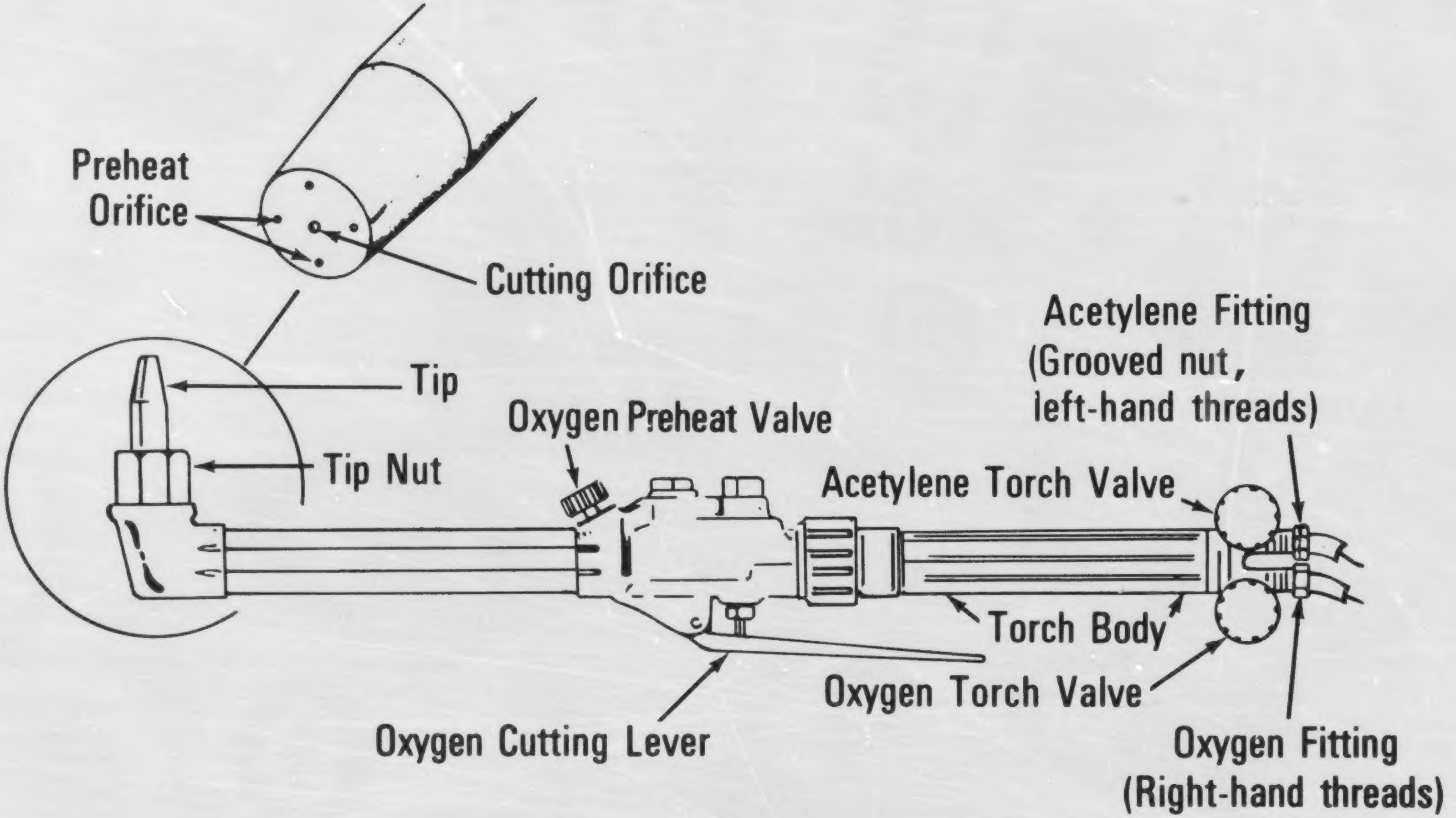
H. Light torch

(NOTE: If heavy smoke comes out of the torch tip and the torch body becomes hot, the flashback has probably traveled past the mixing chamber into the hose. In this case, shut off the oxygen cylinder valve and the acetylene cylinder valve and then notify the instructor.)

Oxyacetylene Cutting Outfit


Oxygen Cylinder Valve
Acetylene Pressure Regulating Screw
Oxygen Regulator
Oxygen Pressure Regulating Screw
Acetylene Regulator
Flashback Check Valve
Acetylene Cylinder Valve
Oxygen Hose
Cutting Attachment
Oxygen Fitting (Right-hand threads)
Oxygen Cutting Lever
Acetylene Cylinder
Safety Chain
Oxygen Torch Valve
Tip Nut
Oxygen Cylinder
Acetylene Torch Valve
Torch Body
Oxygen Preheat Valve
Acetylene Fitting (Grooved nut, left-hand threads)
Tip
Cylinder Truck
Acetylene Hose

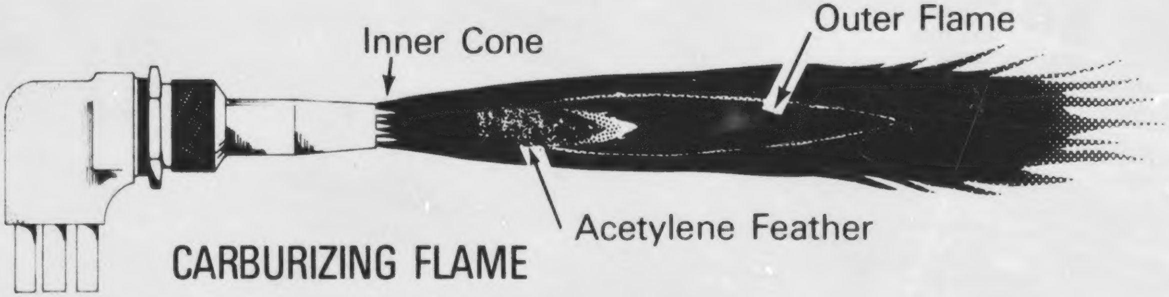
Parts of a Torch Body and Cutting Attachment


Preheat Orifice
Cutting Orifice
Tip
Tip Nut
Oxygen Preheat Valve
Acetylene Fitting (Grooved nut, left-hand threads)
Acetylene Torch Valve
Torch Body
Oxygen Torch Valve
Oxygen Cutting Lever
Oxygen Fitting (Right-hand threads)

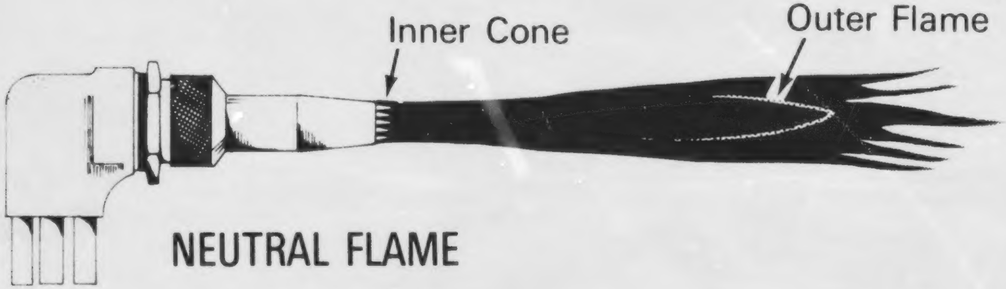
TM 2

D:F - 61-F

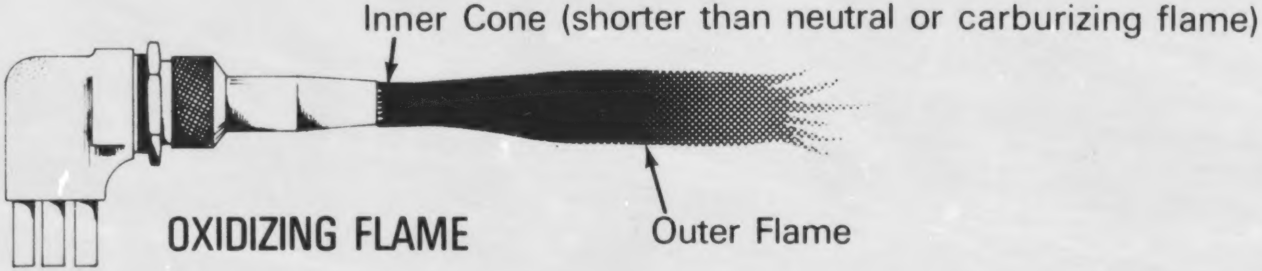
Types of Oxyacetylene Cutting Flames


Inner Cone
Outer Flame
Acetylene Feather

CARBURIZING FLAME


Inner Cone
Outer Flame

NEUTRAL FLAME


Inner Cone (shorter than neutral or carburizing flame)
Outer Flame

OXIDIZING FLAME

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #1--SET UP EQUIPMENT FOR OXYACETYLENE CUTTING

I. Tools and materials

A. Oxygen cylinder

B. Acetylene cylinder

C. Oxygen regulator

D. Acetylene regulator

E. Hoses

F. Wrench

G. Cylinder holder

H. Water container

I. Liquid detergent

J. Clean paintbrush

K. Torch body with tips

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Secure cylinders in a vertical position

B. Remove caps from cylinders

C. Crack valves of each cylinder to remove foreign material; close valves

D. Connect oxygen regulator to oxygen cylinder

(CAUTION: Do not use oil on any connections on the oxyacetylene system.)

1. Turn adjusting screw on regulator counterclockwise until tension on spring is released

2. Turn cylinder valve wide open slowly

JOB SHEET #1

E. Connect acetylene regulator to acetylene cylinder

   1. Turn adjusting screw on regulator counterclockwise until tension on spring is released

   2. Open cylinder valve 1/2 to 3/4 of a turn

      (NOTE: Never open cylinder valve more than 1 1/2 turns.)

F. Connect acetylene hose to acetylene regulator; purge hose

G. Connect oxygen hose to oxygen regulator; purge hose

H. Connect torch body to oxygen and acetylene hoses

I. Close both valves on torch body

J. Attach cutting attachment to torch body

   (NOTE: The tip size is determined by the thickness of metal to be cut and the manufacturer's recommendations.)

K. Close oxygen preheat valve on cutting attachment

L. Turn adjusting screw on oxygen regulator clockwise until correct working pressure is reached

M. Turn adjusting screw on acetylene regulator clockwise until correct working pressure is reached

N. Test all connections for leaks with liquid detergent suds and water

   (NOTE: Apply soap suds with a clean paintbrush.)

OXYACETYLENE CUTTING
UNIT II
JOB SHEET #2--TURN ON, LIGHT, ADJUST TO A NEUTRAL FLAME, AND TURN OFF OXYACETYLENE CUTTING EQUIPMENT

I. Tools and materials

- A. Oxyacetylene cutting outfit
- B. Wrench
- C. Gloves
- D. Safety goggles
- E. Coveralls or protective clothing

II. Procedure for turning on, lighting, and adjusting the cutting torch to a neutral flame

(CAUTION: Follow all shop safety procedures.)

- A. Check all cylinder, regulator, and torch valves to make sure they are closed
- B. Open acetylene cylinder valve 1/2 to 3/4 of a turn

  (NOTE: Never open cylinder valve more than 1 1/2 turns.)
- C. Open acetylene valve on torch one turn
- D. Turn adjusting screw on acetylene regulator clockwise until desired pressure is reached

  (NOTE: Oxygen and acetylene pressures and size of tip depend upon the thickness of metal to be cut. Use pressures and tip size recommended by manufacturer.)
- E. Close acetylene valve on torch
- F. Open oxygen cylinder valve all the way
- G. Open oxygen torch valve all the way
- H. Open oxygen preheat valve on cutting attachment one turn
- I. Turn adjusting screw on oxygen regulator clockwise until desired pressure is reached
- J. Close oxygen preheat valve on cutting attachment
- K. Open acetylene valve on torch 1/4 turn

JOB SHEET #2

L. Light the torch with flint lighter and adjust until smoke on flame clears

M. Open oxygen preheat valve slowly and adjust to a neutral flame

N. Depress the oxygen cutting lever and check to see that a neutral flame is present

(NOTE: If necessary, adjust the oxygen preheat valve with the oxygen cutting lever depressed until a neutral flame is secured.)

III. Procedure for turning off the flame and oxyacetylene unit

A. Close acetylene valve on torch

B. Close oxygen preheat valve

C. Close acetylene cylinder valve

D. Close oxygen cylinder valve

E. Open acetylene valve on torch

(NOTE: When gauges reach "0", close torch valve and release adjusting screw on acetylene regulator by turning counterclockwise.)

F. Open oxygen preheat valve on torch

(NOTE: When gauges reach "0", close oxygen preheat valve and release adjusting screw on oxygen regulator by turning counterclockwise.)

G. Close oxygen valve on torch

H. Place torch and hose on hanger or brackets provided

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #3--MAKE NINETY-DEGREE CUTS ON MILD STEEL AND RESTART A CUT

I. Tools and materials

A. Cutting outfit

B. Mild steel plate 1/4" to 1/2" thick, 4" wide or wider, 8" long or longer

C. Soapstone with a sharp point or edge

D. Straightedge

E. Gloves

F. Safety goggles

G. Pliers

H. Coveralls

I. Flint lighter

J. Welding or cutting table

K. Slag box

L. Can of water

M. Cutting tip

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Mark four parallel lines 2" apart on plate to be cut

B. Adjust oxygen regulator

C. Adjust acetylene regulator

D. Place plate over slag box

E. Light torch

F. Adjust to neutral flame

G. Assume comfortable position

JOB SHEET #3

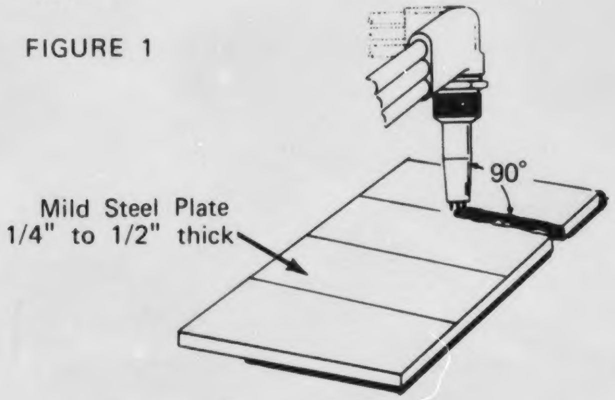
H. Place hoses behind you

I. Maneuver torch with both hands

J. Hold preheat flame with tip of inner cone 1/16" to 1/8" above top of plate at right edge until red spot appears

K. Depress the oxygen cutting lever and move from right to left across the plate (Figure 1)

FIGURE 1



L. Hold the tip at right angle to work while cutting with inner cone being 1/16" to 1/8" above work

M. Make 90° cuts until you have developed the proper procedure

N. Cool metal by placing in can of water with the aid of pliers

O. Show samples to instructor for approval and grading

III. Procedure for restarting a cut

A. Release the oxygen cutting lever

B. Preheat edge only where cutting action was stopped

C. Depress oxygen cutting lever slowly and continue cut

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #4--CUT ROUND STOCK

I. Tools and materials

   A. Cutting outfit

   B. Pieces of reinforcing bar, 1/2", 5/8", 3/4", or 1"

   C. Soapstone with sharp point or edge

   D. Tape measure

   E. Gloves

   F. Safety goggles

   G. Pliers

   H. Coveralls

   I. Flint lighter

   J. Welding or cutting table

   K. Slag box

   L. Can of water

   M. Cutting tip

II. Procedure

   (CAUTION: Follow all shop safety procedures.)

   A. Mark reinforcing bar to desired length

   B. Adjust oxygen and acetylene regulators

   C. Place area to be cut over slag box

   D. Light torch

   E. Adjust to neutral flame

   F. Assume comfortable position

   G. Place hoses behind you

   H. Maneuver torch with both hands

JOB SHEET #4

I. Hold preheat flame with tip of inner cone 1/16" to 1/8" above edge of reinforcing bar until it becomes red

J. Depress the cutting lever and rotate torch tip into the direction of travel until rod is cut (Figure 1)

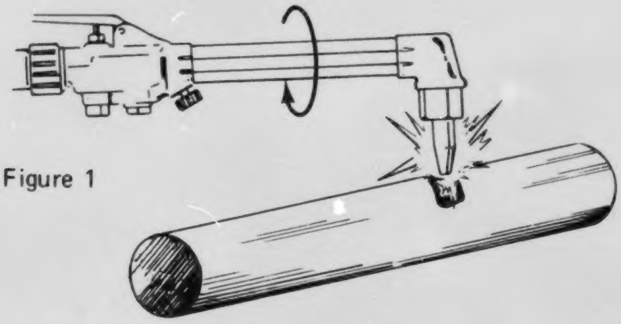


Figure 1

K. Repeat the procedure for each bar or rod

OXYACETYLENE CUTTING
UNIT II

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Fire inside of the torch

_____b. Momentary burning back of the flame into the tip

_____c. Process by which iron or steel is heated to a temperature where it can be rapidly oxidized by high purity oxygen flowing under pressure through a cutting torch

_____d. Metal container with a layer of water or sand to catch hot slag

_____e. Situation in which the most distant portion of the cutting stream lags behind the stream nearest the cutting tip

_____f. Combining oxygen with another substance

_____g. Substance that is produced when oxygen is combined with an element

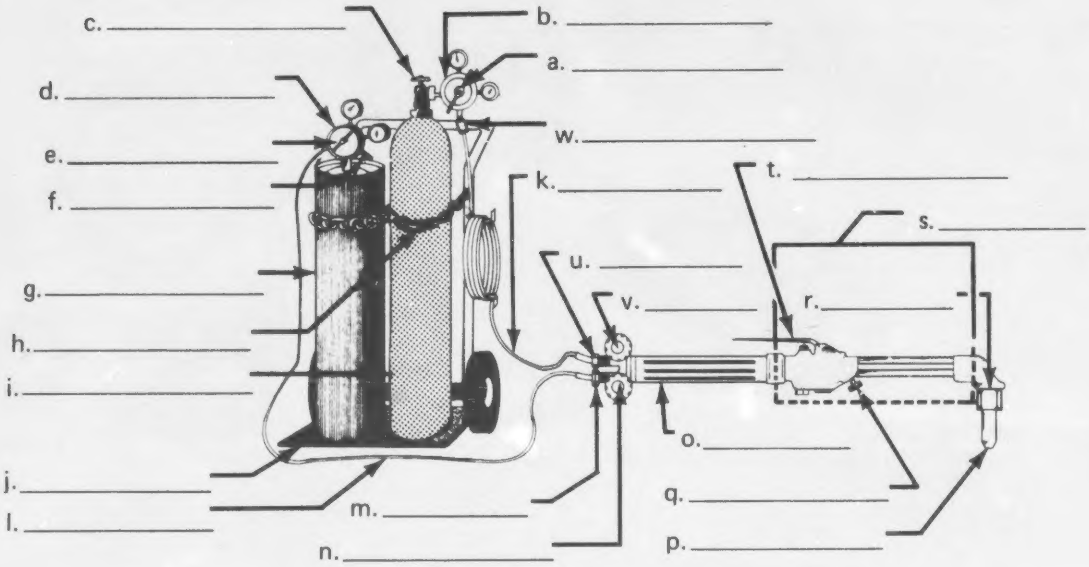
_____h. Area of material removed from a piece of metal by a saw or cutting torch

_____i. To remove any foreign material from a system or component by flushing with the gas used in that system

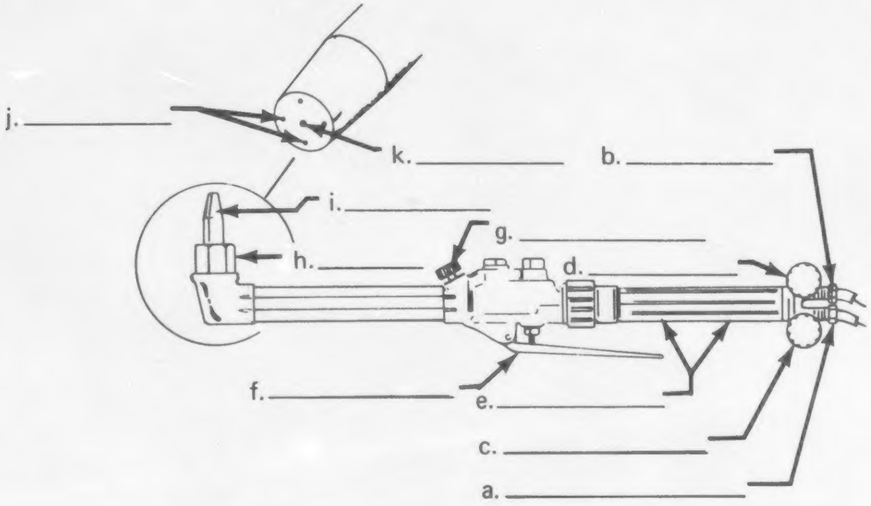
_____j. Metal which melts away during the oxyacetylene cutting process

1. Slag box
2. Oxidizing
3. Flashback
4. Dragline
5. Oxide
6. Backfire
7. Kerf
8. Purge
9. Flame cutting
10. Slag

2. Identify the parts of the oxyacetylene cutting outfit by writing the correct names in the blanks.


c.
b.
a.
d.
w.
e.
k.
t.
f.
s.
u.
g.
v.
r.
h.
i.
o.
j.
q.
m.
l.
p.
n.

3. Identify the parts of the torch body and cutting attachment by writing the correct names in the blanks.


j.
k.
b.
i.
g.
h.
d.
f.
e.
c.
a.

4. List eight rules for the safe handling of oxygen and acetylene equipment.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

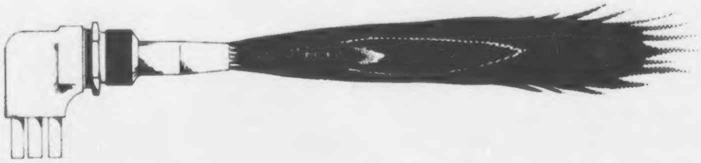
e. ______________________________

f. ______________________________

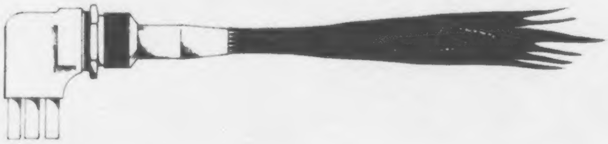
g. ______________________________

h. ______________________________

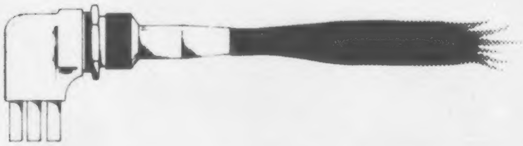
5. Identify the following three types of flames.



a. ______________________________



b. ______________________________



c. ______________________________

6. List five reasons for poor cuts.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

7. Select the causes of a backfire by placing an "X" in the appropriate blanks.

   _____a. Too much oxygen

   _____b. Insufficient acetylene or oxygen pressure

   _____c. Too much acetylene

   _____d. Loose cutting tip

   _____e. Overheating of cutting tip

   _____f. Bad "O" ring in torch body

   _____g. Dirty tip

8. Arrange in order the steps involved when a backfire occurs by placing the correct sequence number in the appropriate blank.

   _____a. A loud snap or pop is emitted from the torch

   _____b. Flame burns momentarily back into the tip

   _____c. Flame either goes out or continues to burn in normal manner

9. Select true statements concerning what happens when a flashback occurs by placing an "X" in the appropriate blanks.

   _____a. Flame appears outside the torch body

   _____b. Squealing noise, smoke, and/or sparks are emitted from the torch tip

10. List in the proper order the steps to follow in case of a flashback.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

e. ____

f. ____

g. ____

h. ____

11. Demonstrate the ability to:

    a. Set up equipment for oxyacetylene cutting.

    b. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment.

    c. Make ninety-degree cuts on mild steel and restart a cut.

    d. Cut round stock.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

OXYACETYLENE CUTTING
UNIT II

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 9
   d. 1
   e. 4
   f. 2
   g. 5
   h. 7
   i. 8
   j. 10

2. a. Oxygen pressure regulating screw
   b. Oxygen regulator
   c. Oxygen cylinder valve
   d. Acetylene regulator
   e. Acetylene pressure regulating screw
   f. Acetylene cylinder valve
   g. Acetylene cylinder
   h. Safety chain
   i. Oxygen cylinder
   j. Cylinder truck
   k. Oxygen hose
   l. Acetylene hose
   m. Acetylene fitting
   n. Acetylene torch valve
   o. Torch body
   p. Tip
   q. Oxygen preheat valve
   r. Tip nut
   s. Cutting attachment
   t. Oxygen cutting lever
   u. Oxygen fitting
   v. Oxygen torch valve

3. a. Oxygen fitting
   b. Acetylene fitting
   c. Oxygen torch valve
   d. Acetylene torch valve
   e. Torch body
   f. Oxygen cutting lever
   g. Oxygen preheat valve
   h. Tip nut
   i. Tip
   j. Preheat orifice
   k. Cutting orifice

4. Any eight of the following:

   a. Secure cylinders in an upright position to prevent damage to valves or regulators
   b. Purge cylinder valve before attaching regulators
   c. Release adjusting screws on regulator before opening cylinder valve
   d. Stand to one side of regulator while slowly opening the cylinder valve
   e. Do not use acetylene at pressures higher than 15 psi

- f. Purge oxygen and acetylene passages before lighting torch
- g. Light acetylene gas before opening oxygen valve on torch
- h. Do not use oil on regulators, torches, fittings, or any place that it may come in contact with oxygen
- i. Do not use oxygen as a substitute for compressed air
- j. Keep heat, flames, and sparks away from combustibles
- k. Use safety goggles, gloves, and protective clothing
- l. Test connections for leaks with soapsuds and paintbrush
- m. Do not weld on containers that have been used for combustible materials
- n. Avoid breathing toxic fumes when welding
- o. Do not leave a burning torch unattended
- p. Do not cut a weld near concrete
- q. Operate torch in a well-ventilated place
- r. Weld or cut at least five feet from cylinders
- s. Protect hoses from hot metal, rupture, or mechanical damage
- t. Others as added by instructor

5. a. Carburizing
   b. Neutral
   c. Oxidizing

6. Any five of the following:

   a. Preheat flames too small
   b. Preheat flames too long
   c. Oxygen pressure too low
   d. Oxygen pressure too high; nozzle size too small
   e. Cutting speed too slow
   f. Cutting speed too fast
   g. Blowpipe travel unsteady
   h. Cut lost and not carefully restarted

7. b, d, e, f, g

8. a. 2
   b. 1
   c. 3

9. b

10. a. Close oxygen preheat valve
    b. Close oxygen torch valve
    c. Close acetylene torch valve
    d. Release oxygen regulator screw
    e. Release acetylene regulator screw
    f. Examine acetylene unit
    g. Reset regulator pressures
    h. Light torch

11. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE FUSION WELDING
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to demonstrate the ability to light, adjust, and turn off the oxyacetylene welding equipment, handle the equipment properly, and make welds with or without filler rod. The student should also be able to select proper tip size and list factors that determine the correct type of filler rod to use. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with oxyacetylene fusion welding with the correct definitions.
2. Identify the parts of oxyacetylene fusion welding equipment.
3. Select factors that determine weld quality.
4. List properties of a good weld.
5. Select factors that determine tip size in oxyacetylene welding.
6. List two factors that determine the type of filler rod to use in oxyacetylene welding.
7. State the purpose of a filler rod.
8. Identify types of oxyacetylene fusion welding flames.
9. Demonstrate the ability to:
    a. Turn on, light, adjust, and turn off oxyacetylene welding equipment.
    b. Construct a corner weld without filler rod.
    c. Lay beads on gauge metal without filler rod.
    d. Lay beads on gauge metal with filler rod.
    e. Weld butt joints with filler rod.

OXYACETYLENE FUSION WELDING
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Secure films on oxyacetylene fusion welding to show to the class.

VIII. Have students make a list of different types of metal.

IX. Have students draw a butt weld.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Oxyacetylene Fusion Welding Equipment
    2. TM 2--Welding Torches
    3. TM 3--Welding Regulators
    4. TM 4--Oxyacetylene Fusion Welding Flames
  D. Job sheets
    1. Job Sheet #1--Turn On, Light, Adjust, and Turn Off Oxyacetylene Welding Equipment
    2. Job Sheet #2--Construct a Corner Weld Without Filler Rod
    3. Job Sheet #3--Lay Beads on Gauge Metal Without Filler Rod

4. Job Sheet #4--Lay Beads on Gauge Metal with Filler Rod

5. Job Sheet #5--Weld Butt Joints with Filler Rod

E. Test

F. Answers to test

II. References:

A. *Smith's Instructor's Manual for a Basic Course in Oxyacetylene Brazing, Cutting, and Welding.* Form 424. Minneapolis, Minnesota: Smith Welding Equipment Tescom Corporation.

B. *Smith's Instructor's Manual Answer Key.* Form 429, Minneapolis, Minnesota: Smith Welding Equipment/Divison of Tescom Corp.

C. Phipps, Lloyd J.; McColly, H. F.; Scranton, L. L.; and Cook, G. C. *Farm Mechanics Text and Handbook.* Danville, Illinois: The Interstate Printers and Publishers, Inc.

D. Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A. *Modern Welding.* Homewood, Illinois: Goodheart-Willcox Co., Inc. 1965.

E. *The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures.* New York: Linde Division/Union Carbide Corp.

OXYACETYLENE FUSION WELDING
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. Fusion welding--Joining of pieces of metal by heating the adjoining edges to the fusion or melting point and allowing them to flow or run together and then cool

   B. Penetration--Distance from the original surface of the base metal to that point at which fusion ceases

   C. Base metal--Metal to be welded

   D. Alloy--Mixture with metallic properties; composed of two or more elements of which at least one is a metal

   E. Inner cone--Inner white part of a neutral flame

   F. Tack weld--Short weld used for temporarily holding metal in place

   G. Backfire--Momentary burning back of the flame into the tip; flame goes out with a loud snap or pop

   H. Flashback--Fire inside the torch; indicated by a hissing or squealing sound

   (CAUTION: This is a very dangerous condition.)

II. Oxyacetylene fusion welding equipment (Transparencies 1, 2, and 3)

   A. Acetylene cylinder

   B. Acetylene cylinder valve

   C. Acetylene fitting

   D. Acetylene regulator

   E. Oxygen cylinder

   F. Oxygen cylinder valve

   G. Oxygen fitting

   H. Oxygen regulator

   I. Oxygen torch valve

INFORMATION SHEET

  J. Torch body

  K. Acetylene torch valve

  L. Welding tip

  M. Welding goggles

  N. Welding gloves

  O. Safety chain

  P. Flint lighter

  Q. Cylinder truck

  R. Oxygen hose

  S. Acetylene hose

III. Factors that determine weld quality

  A. Proper flame adjustment

  B. Angle of tip

  C. Distance from work

  D. Speed of travel

  E. Movement of tip

IV. Properties of a good weld

  A. Consistent width

  B. Straightness

  C. Slightly crowned

  D. Fused into base metal

  E. Clean appearance

V. Factors that determine tip size

  A. Thickness of metal

  B. Size of welding rod

  (NOTE: Always use manufacturer's recommendation on tip size.)

INFORMATION SHEET

VI. Factors that determine filler rod selection

  A. Rod with similar properties as base metal

  B. Thickness of metal

  (NOTE: A general rule is to use a rod with a diameter equal to the thickness of the base metal.)

VII. Purpose of filler rod--To add strength to weld or joint

VIII. Oxyacetylene fusion welding flames (Transparency 4)

  A. Carburizing flame

  (NOTE: The flame contains an excess of acetylene and is identified by an acetylene feather visible on the inner cone. It is recommended for welding cast iron. Carbon is introduced into the weld, causing hardening of the metal.)

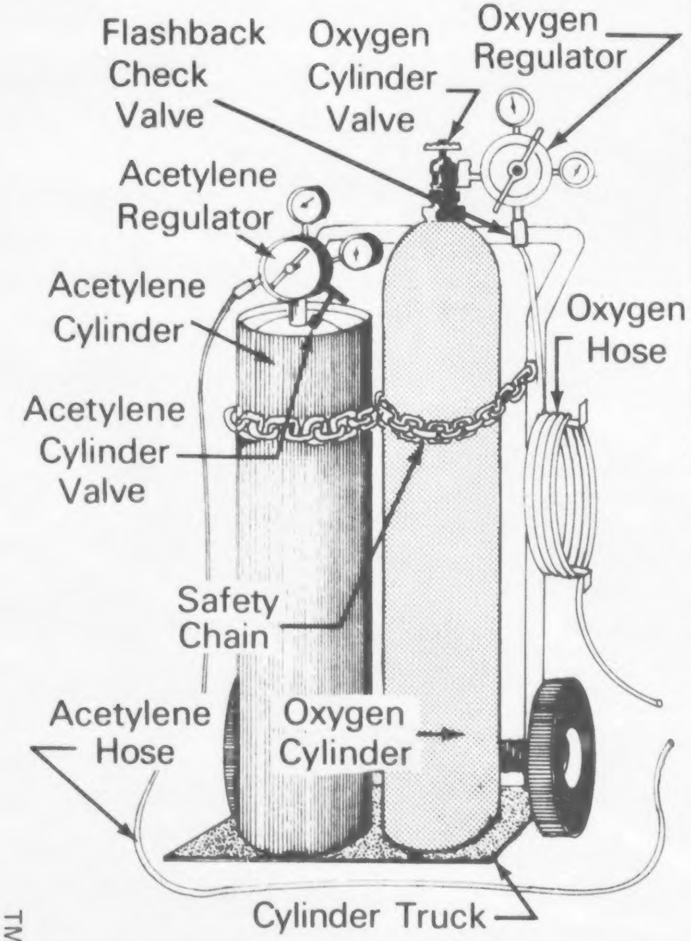
  B. Neutral flame

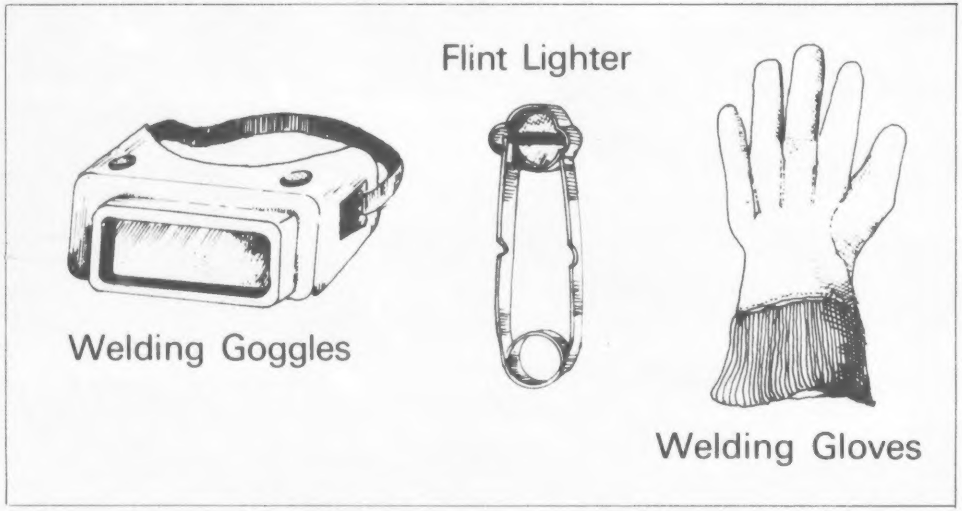
  (NOTE: The flame burns equal parts of oxygen and acetylene at a temperature of approximately 5950°F or 3270°C. It is identified by a clear, well-defined white inner cone.)

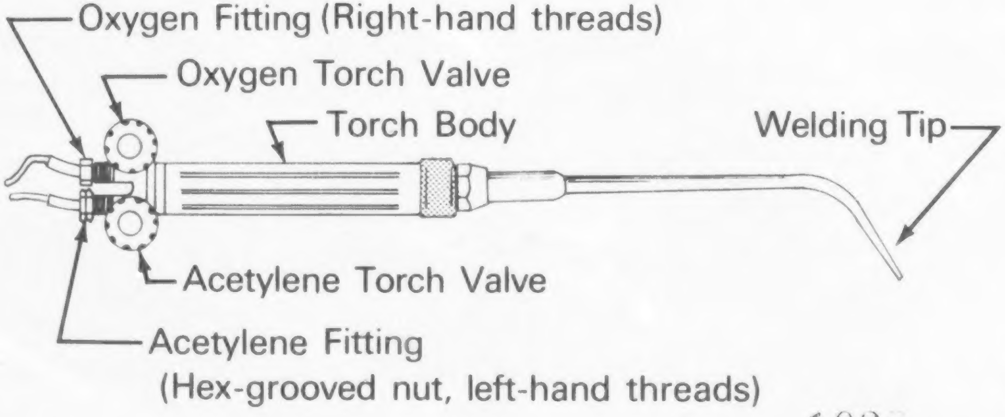
  C. Oxidizing flame

  (NOTE: The flame burns an excess of oxygen and is identified by a short inner cone. It is the hottest of the three types of welding flames. It oxidizes the metal, causing it to harden and become brittle, and is therefore not recommended for welding most metals. It is recommended for brazing when slightly oxidized.)

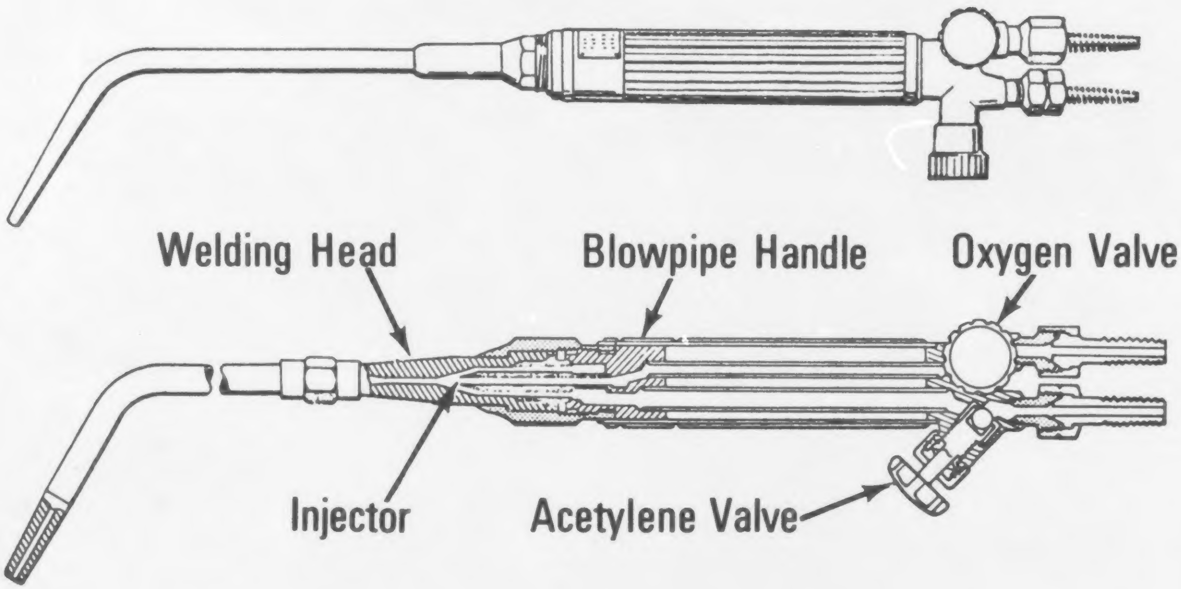
Oxyacetylene Fusion Welding Equipment


Flashback Check Valve
Oxygen Cylinder Valve
Oxygen Regulator
Acetylene Regulator
Acetylene Cylinder
Acetylene Cylinder Valve
Oxygen Hose
Safety Chain
Acetylene Hose
Oxygen Cylinder
Cylinder Truck


Flint Lighter
Welding Goggles
Welding Gloves

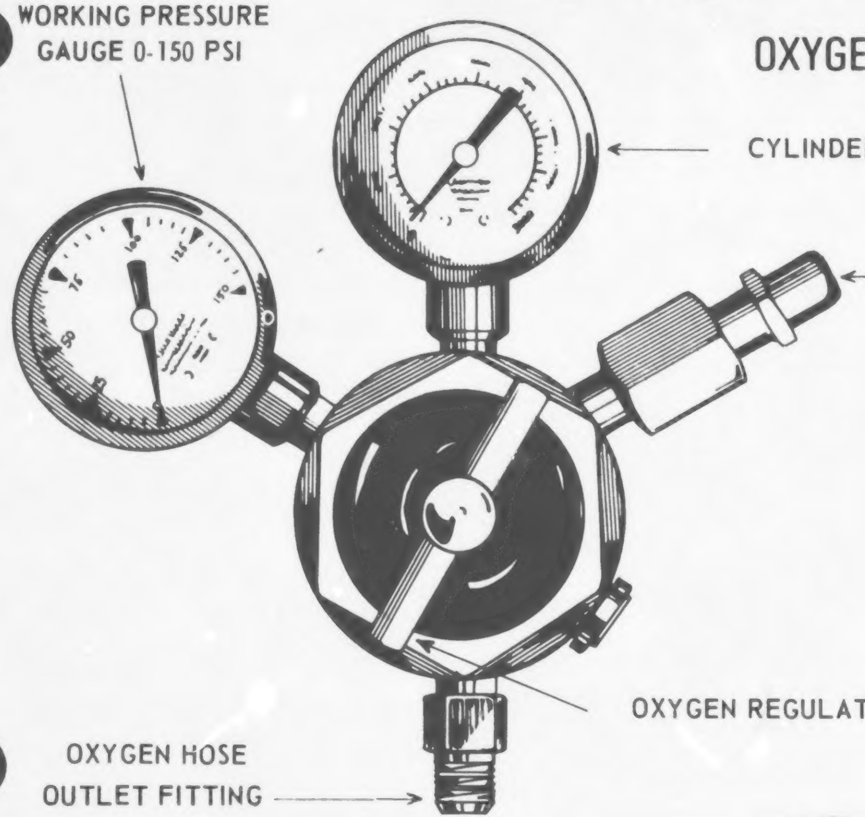

Oxygen Fitting (Right-hand threads)
Oxygen Torch Valve
Torch Body
Welding Tip
Acetylene Torch Valve
Acetylene Fitting (Hex-grooved nut, left-hand threads)

Welding Torches

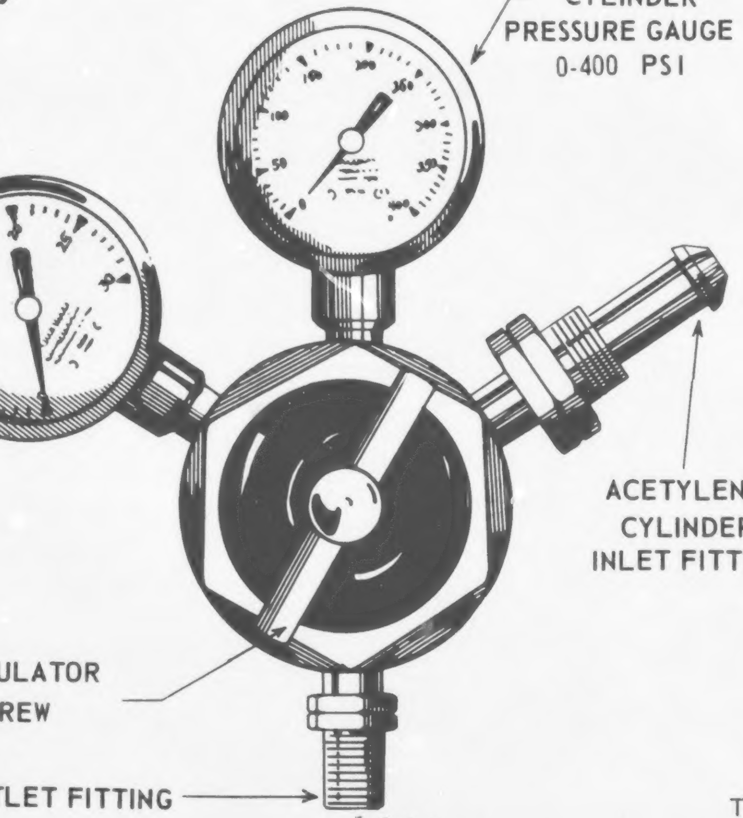

Welding Head
Blowpipe Handle
Oxygen Valve
Injector
Acetylene Valve

Welding Regulators

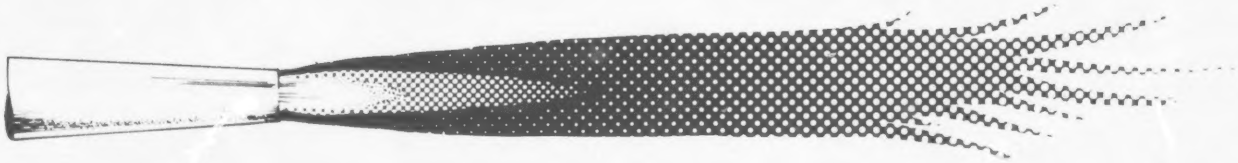
OXYGEN REGULATOR GAUGES


WORKING PRESSURE
GAUGE 0-150 PSI
CYLINDER PRESSURE GAUGE 0 to 3000 PSI
OXYGEN CYLINDER
INLET FITTING
OXYGEN REGULATOR ADJUSTING SCREW
OXYGEN HOSE
OUTLET FITTING

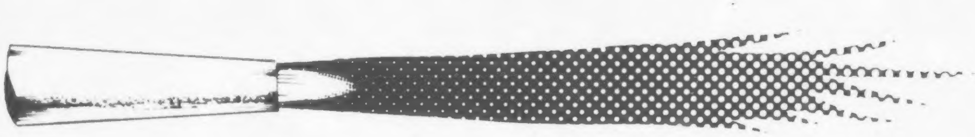
ACETYLENE REGULATOR


CYLINDER
PRESSURE GAUGE
0-400 PSI
WORKING
PRESSURE GAUGE
0 TO 30 PSI
ACETYLENE
CYLINDER
INLET FITTING
ACETYLENE REGULATOR
ADJUSTING SCREW
ACETYLENE HOSE OUTLET FITTING

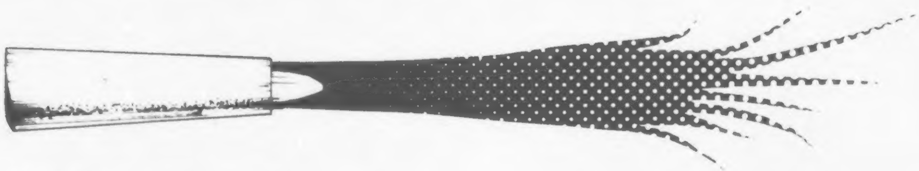
Oxyacetylene Fusion Welding Flames



Carburizing Flame



Neutral Flame



Oxidizing Flame

TM 4

D:F - 95-F

D:F - 97-F

OXYACETYLENE FUSION WELDING
UNIT III

JOB [illegible] 1--TURN ON, LIGHT, ADJUST, AND TURN OFF OXYACETYLENE WELDING EQUIPMENT

I. Tools and materials

- A. Oxygen cylinder
- B. Acetylene cylinder
- C. Hoses
- D. Oxygen and acetylene regulators
- E. Torch body and welding tips
- F. Cylinder holder and hose rack
- G. Flint lighter
- H. Welding goggles with #5 lens
- I. Appropriate gloves

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Turn on and light torch

1. Check all cylinder, regulator, and torch valves to make sure they are turned off

2. Open acetylene cylinder valve 1/2 to 3/4 of a turn

   (CAUTION: Never open valve more than 1 1/2 turns.)

3. Open acetylene valve on torch one turn to purge line

   (CAUTION: Acetylene pressure should never exceed 15 psi.)

4. Turn acetylene regulator pressure adjusting screw clockwise until desired working pressure is reached

   (NOTE: The working pressure is determined by the size of the tip.)

5. Close acetylene valve on torch

6. Open oxygen cylinder valve all the way and tighten in open position

JOB SHEET #1

7. Open oxygen torch valve one turn
8. Turn oxygen regulator pressure adjusting screw clockwise until desired pressure is reached

   (NOTE: The working pressure is determined by the size of the tip.)

9. Close oxygen valve on torch
10. Open acetylene valve on torch 1/4 turn
11. Light the torch with flint lighter and adjust until smoke on flame clears
12. Open oxygen torch valve and adjust to a neutral flame with a tiny trace of feather on the inner cone

B. Adjust welding torch for the three types of flames, starting with a neutral flame

(NOTE: To produce a carburizing flame, reduce the supply of oxygen by slowly closing the oxygen torch valve until an excess acetylene feather is produced. To produce an oxidizing flame, increase the supply of oxygen by slowly opening the oxygen torch valve until a short, white inner cone is produced.)

C. Turn off the torch and oxyacetylene welding unit

1. Close acetylene torch valve
2. Close oxygen torch valve
3. Close acetylene cylinder valve
4. Close oxygen cylinder valve
5. Open acetylene torch valve

   (NOTE: When gauges reach 0, release acetylene regulator pressure adjusting screw and close torch valve.)

6. Open oxygen valve on torch

   (NOTE: When gauges reach 0, release oxygen regulator pressure adjusting screw and close torch valve.)

   (CAUTION: Do not open the acetylene and oxygen torch valves at the same time.)

7. Place torch and hoses on hanger or brackets

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #2--CONSTRUCT A CORNER WELD WITHOUT FILLER ROD

I. Tools and materials

  A. Oxyacetylene welding unit

  B. Welding tip (according to manufacturer's recommendations)

  C. Gloves

  D. Goggles

  E. Pliers

  F. Wire brush

  G. Flint lighter

  H. Firebrick

  I. Mild steel, 2 strips of 16 gauge, 1 1/4" x 6"

II. Procedure

(CAUTION: Follow all shop safety procedures.)

  A. Prepare metal for welding

  B. Place metal in welding position

  C. Turn on oxyacetylene unit

  D. Set working pressure

  (NOTE: Refer to manufacturer's recommendations.)

  E. Light torch and adjust to a neutral flame with very slight feather

  F. Tack weld metal in position

  G. Place inner cone about 1/16" to 1/8" from plate

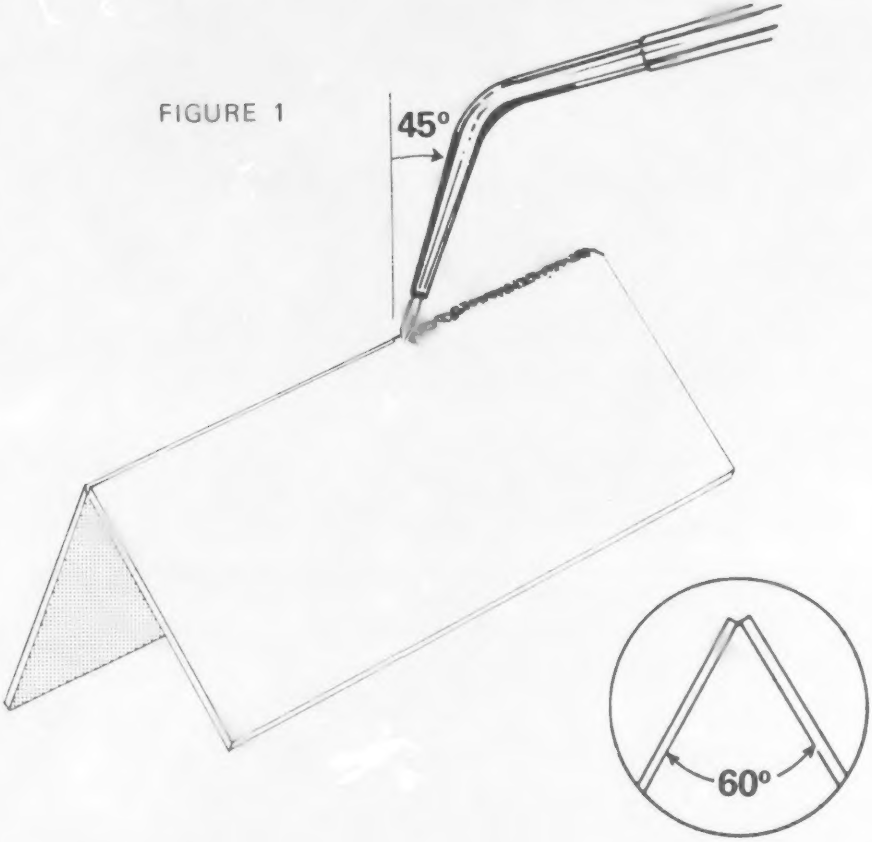
  (NOTE: Do not begin travel until you have established a molten puddle.)

  H. Begin welding at right end

JOB SHEET #2

I. Hold tip vertically at 45° angle from direction of travel (Figure 1)

FIGURE 1



J. Move flame slowly down the joint, forming a puddle as you travel from right to left

K. Examine welded joint for good bead characteristics and penetration

L. Show welded joint to instructor

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #3--LAY BEADS ON GAUGE METAL WITHOUT FILLER ROD

I. Tools and materials

  A. Oxyacetylene welding unit

  B. Welding tip (according to manufacturer's recommendations)

  C. Gloves

  D. Goggles

  E. Pliers

  F. Wire brush

  G. Flint lighter

  H. Firebrick

  I. Mild steel, 1 strip of 16 gauge, 1 1/4" x 6"

II. Procedure

(CAUTION: Follow all shop safety procedures.)

  A. Prepare metal for welding

  B. Place metal in welding position

  C. Turn on oxyacetylene unit

  D. Set working pressure

  (NOTE: Refer to manufacturer's recommendations.)

  E. Light torch and adjust to a neutral flame

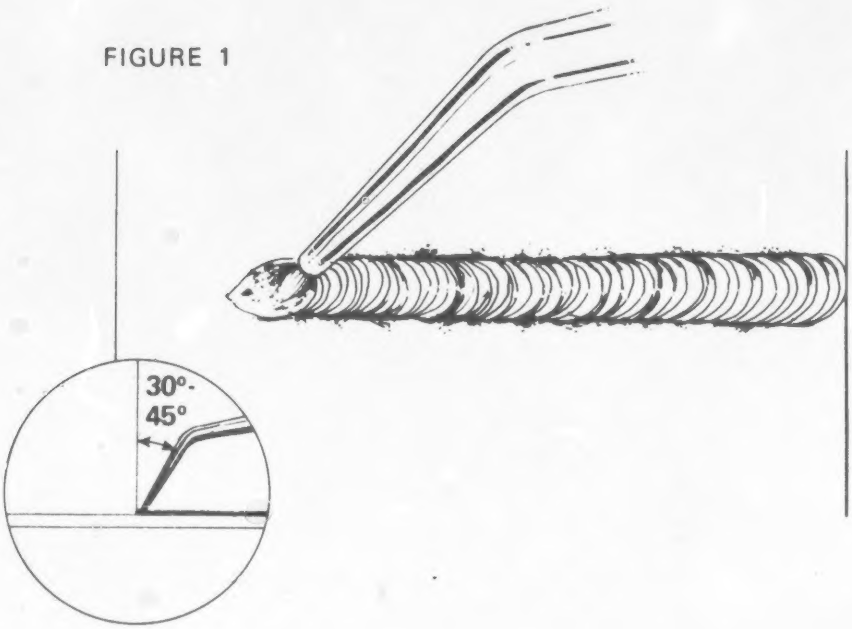
  F. Place inner cone about 1/16" to 1/8" from metal

  (NOTE: Do not begin travel until you have established a molten puddle.)

JOB SHEET #3

G. Hold torch 30° to 45° from center in direction of travel (Figure 1)

FIGURE 1



H. Move the torch forward slowly, allowing the metal to melt

I. Show beads to instructor

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #4--LAY BEADS ON GAUGE METAL WITH FILLER ROD

I. Tools and materials

A. Oxyacetylene welding unit

B. Welding tip (according to manufacturer's recommendations)

C. Gloves

D. Goggles

E. Pliers

F. Wire brush

G. Flint lighter

H. Firebrick

I. Mild steel, 1 strip of 16 gauge, 1 1/4" x 6"

J. Mild steel filler rod (according to manufacturer's recommendations)

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Prepare metal for welding

B. Place metal in welding position

C. Turn on oxyacetylene unit

D. Set working pressure

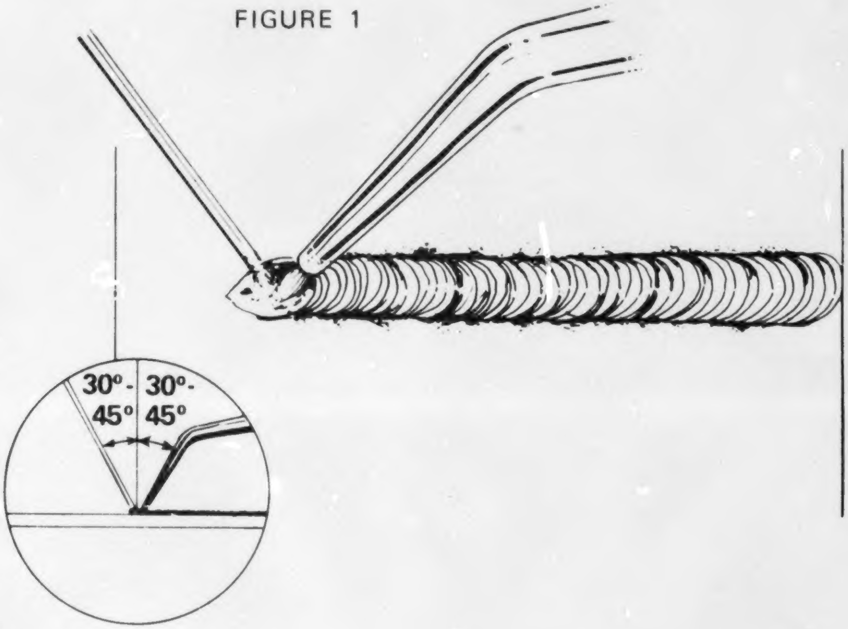
(NOTE: Refer to manufacturer's recommendations.)

E. Light torch and adjust to a neutral flame

JOB SHEET #4

F. Hold torch 30° to 45° from center (Figure 1)

FIGURE 1



G. Place inner cone about 1/16" to 1/8" from surface of puddle

(NOTE: Do not begin travel until you have established a molten puddle.)

H. Add filler rod to front edge of puddle in front of torch

I. Move puddle forward with torch and allow puddle to form in base metal

J. Add rod to front edge of puddle and withdraw rod as you move puddle forward

K. Keep puddle the same size and shape for the entire length of the bead

L. Show bead to instructor when completed

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #5--WELD BUTT JOINTS WITH FILLER ROD

I. Tools and materials

A. Oxyacetylene welding unit

B. Welding tip (according to manufacturer's recommendations)

C. Gloves

D. Goggles

E. Pliers

F. Wire brush

G. Flint lighter

H. Firebrick

I. Mild steel, 2 strips of 16 gauge, 1 1/4" x 6"

J. Mild steel filler rod (according to manufacturer's recommendations)

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Prepare metal for welding

B. Place metal in welding position

C. Turn on oxyacetylene unit

D. Set working pressure

(NOTE: Refer to manufacturer's recommendations.)

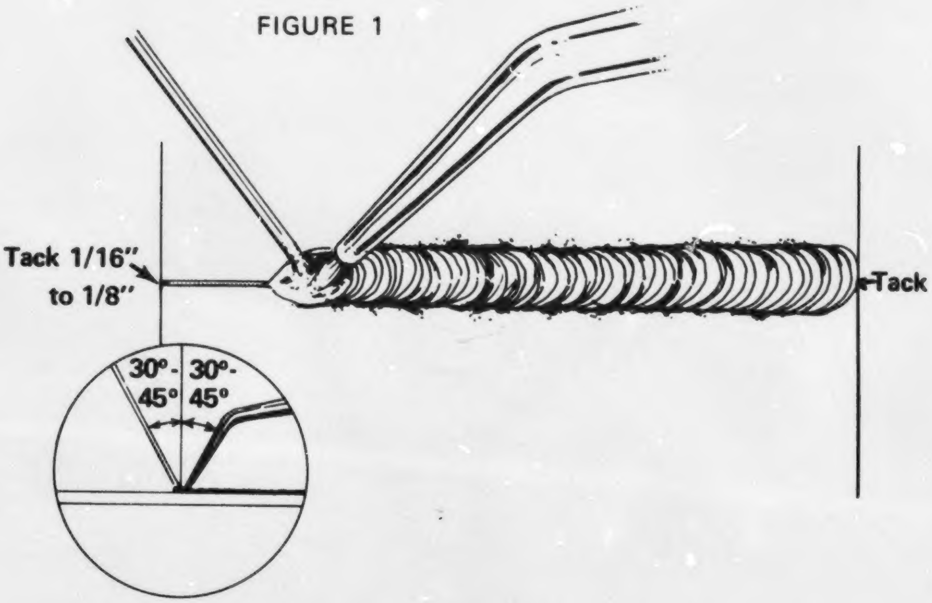
E. Light torch and adjust to a neutral flame

F. Tack weld metal together at both ends of joint

JOB SHEET #5

G. Hold torch 30° to 45° from center (Figure 1)

FIGURE 1



(NOTE: Do not begin travel until you have established a molten puddle.)

H. Place inner cone about 1/16" to 1/8" from surface of puddle

I. Add filler rod to front edge of puddle in front of torch

J. Move puddle forward with torch and allow puddle to form in base metal

K. Add rod to front edge of puddle and withdraw rod as you move puddle forward

L. Keep puddle the same size and shape for the entire length of the bead

M. Show bead to instructor

D:F - 107-F

OXYACETYLENE FUSION WELDING
UNIT III

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Metal to be welded

______b. Fire inside the torch; indicated by a hissing or squealing sound

______c. Joining of pieces of metal by heating the adjoining edges to the fusion or melting point and allowing them to flow or run together and then cool

______d. Inner white part of a neutral flame

______e. Distance from the original surface of the base metal to that point at which fusion ceases

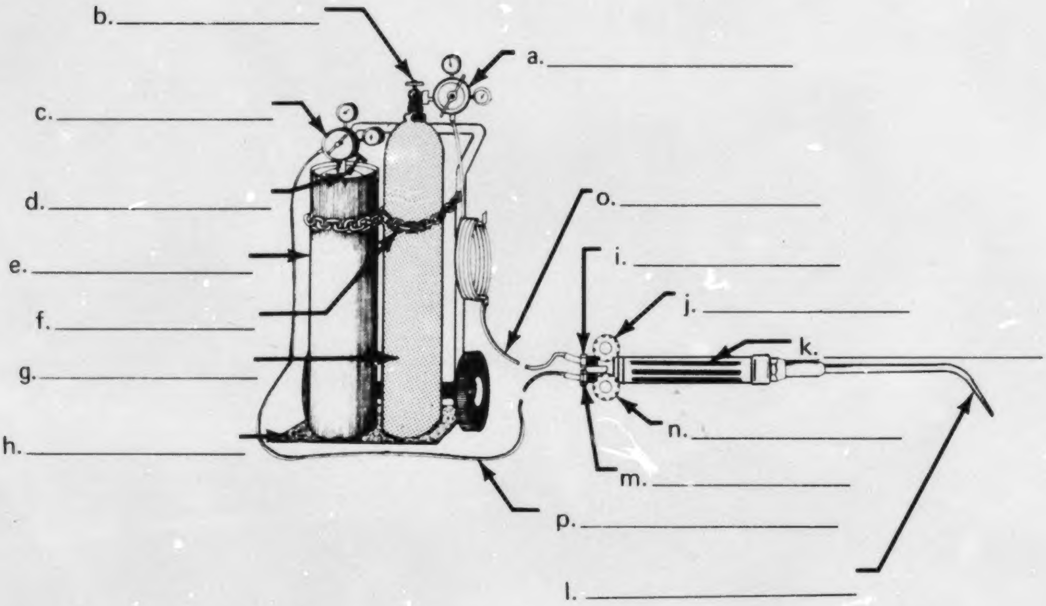
______f. Short weld used for temporarily holding metal in place

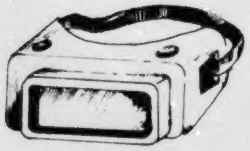
______g. Mixture with metallic properties; composed of two or more elements of which at least one is a metal

______h. Momentary burning back of the flame into the tip; flame goes out with a loud snap or pop

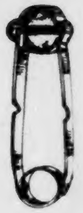
1. Tack weld
2. Flashback
3. Backfire
4. Inner cone
5. Alloy
6. Base metal
7. Penetration
8. Fusion welding

2. Identify the parts of the oxyacetylene fusion welding equipment illustrated below by writing the correct names in the blanks.

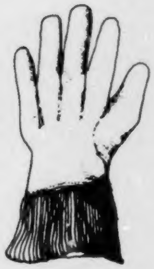

b. ____________
a. ____________
c. ____________
d. ____________
o. ____________
e. ____________
i. ____________
f. ____________
j. ____________
k. ____________
g. ____________
h. ____________
n. ____________
m. ____________
p. ____________
l. ____________



q. ____________



r. ____________



s. ____________

3. Select factors that determine weld quality by placing an "X" in the appropriate blanks.

   _____a. Proper flame adjustment

   _____b. Angle of tip

   _____c. Distance from work

   _____d. Thickness of metal

   _____e. Speed of travel

   _____f. Movement of tip

   _____g. Width of bead

4. List three properties of a good weld.

   a. ______________________________

   b. ______________________________

   c. ______________________________

5. Select factors that determine tip size by placing an "X" in the appropriate blanks.

   _____a. Size of welding rod

   _____b. Temperature of metal

   _____c. Thickness of metal

   _____d. Distance to work

6. List two factors that determine the type of filler rod to use in oxyacetylene welding.

   a. ______________________________

   b. ______________________________

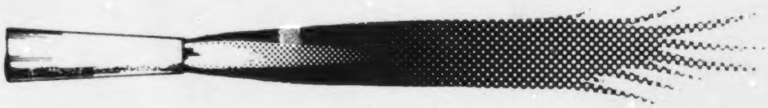
7. State the purpose of a filler rod.

   ____

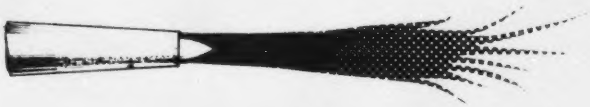
   ____

   ____

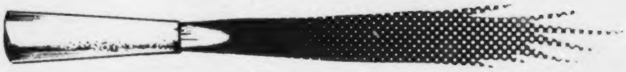
8. Identify the three types of oxyacetylene fusion welding flames illustrated below by writing the correct names in the blanks.



a. ______________________



b. ______________________



c. ______________________

9. Demonstrate the ability to:

a. Turn on, light, adjust, and turn off oxyacetylene welding equipment.

b. Construct a corner weld without filler rod.

c. Lay beads on gauge metal without filler rod.

d. Lay beads on gauge metal with filler rod.

e. Weld butt joints with filler rod.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

OXYACETYLENE FUSION WELDING
UNIT III

ANSWERS TO TEST

1. a. 6 e. 7
   b. 2 f. 1
   c. 8 g. 5
   d. 4 h. 3

2. a. Oxygen regulator
   b. Oxygen cylinder valve
   c. Acetylene regulator
   d. Acetylene cylinder valve
   e. Acetylene cylinder
   f. Safety chain
   g. Oxygen cylinder
   h. Cylinder truck
   i. Oxygen fitting
   j. Oxygen torch valve
   k. Torch body
   l. Welding tip
   m. Acetylene fitting
   n. Acetylene torch valve
   o. Oxygen hose
   p. Acetylene hose
   q. Welding goggles
   r. Flint lighter
   s. Welding gloves

3. a, b, c, e, f

4. Any three of the following:

   a. Consistent width
   b. Straightness
   c. Slightly crowned
   d. Fused into base metal
   e. Clean appearance

5. a, c

6. a. Rod with similar properties as base metal
   b. Thickness of metal

7. To add strength to weld or joint

8. a. Carburizing
   b. Oxidizing
   c. Neutral

9. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE BRAZE WELDING
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to differentiate between braze welding and fusion welding and list advantages and disadvantages of braze welding. The student should also be able to demonstrate the ability to braze weld a square groove butt joint. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with braze welding with the correct definitions.
2. List advantages and disadvantages of braze welding.
3. List three advantages of having a chemically clean metal surface in braze welding.
4. Select methods for removing oxides from a clean metal surface.
5. Differentiate between braze welding and fusion welding.
6. List purposes for using flux.
7. Match temperatures of molten bronze with the correct reactions.
8. Demonstrate the ability to braze weld a square groove butt joint.

OXYACETYLENE BRAZE WELDING
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Secure film on braze welding from a local welding supplier to show to the class.

VIII. Have students make a list of different size bronze rods.

IX. Have students draw different welds.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency Master 1--Braze Welding a Butt Joint

  D. Job Sheet #1--Braze Weld a Square Groove Butt Joint

  E. Test

  F. Answers to test

II. References:

  A. *The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures*. New York: Linde Div./Union Carbide Corp., 1960.

  B. Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A., *Modern Welding*. Homewood, Illinois: Goodheart-Willcox Co., Inc., 1965.

  C. Giachino, J. W.; Weeks, William; and Brune, Elmer. *Welding Skills and Practices*. Chicago: American Technical Society, 1967.

OXYACETYLENE BRAZE WELDING
UNIT IV

INFORMATION SHEET

I. Terms and definitions

   A. Braze welding--Heating the base metal to a dull red color and depositing a bead over the seam (joint) with a bronze filler rod; the base metal is not melted (Transparency 1)

   B. Malleability--Property of metals which allows them to be bent or permanently distorted without rupture; opposite of brittleness

   C. Ductile--Capable of being drawn or stretched out

   D. Tinning operation--Melting a small amount of bronze rod onto the surface and allowing it to spread along the entire seam (joint)

   (NOTE: It is this flow of the thin film of bronze which is known as *tinning.*)

   E. Flux--Chemical used to clean metals and to promote fusion during the welding process

II. Advantages and disadvantages of braze welding

   A. Advantages

      1. Provides less chance of destroying main characteristics of base metal since it is not heated to a molten condition

      2. Consumes less gas

      3. Can be used on thin metals

      4. Used on malleable castings

      5. Increases speed of joining metals

      6. May be used to join different kinds of metals

   B. Disadvantages

      1. Cannot be used on metal where stress is a factor

      2. Expensive to use

INFORMATION SHEET

3. Not recommended for parts which are raised to temperatures higher than the melting point of bronze, either in service or during heat treatment

   (NOTE: Bronze will lose its strength at temperatures above 500°F or 260°C.)

4. Will not bond unless base metal has corrosion-resistant properties similar to bronze

III. Importance of a chemically clean metal surface in braze welding

- A. Ensures that the molten bronze will stick to the base metal
- B. Has a stronger bond on base metal
- C. Allows bronze to flow smoothly and evenly over entire weld area

IV. Methods for removing oxides from clean metal surface

- A. Mechanical means
  - 1. Wire brush
  - 2. Grinder
- B. Chemical means--Flux

(NOTE: Both methods should be used to completely remove the oxides.)

V. Differences between braze welding and fusion welding

- A. Braze welding
  - 1. The base metal is not melted

    (NOTE: The base metal is heated only to a dull red color.)
  - 2. An alloy rod is used to lay a thin coat of bronze along the seam
- B. Fusion welding
  - 1. Base metal is melted and joined
  - 2. Rod with similar characteristics of base metal must be used

INFORMATION SHEET

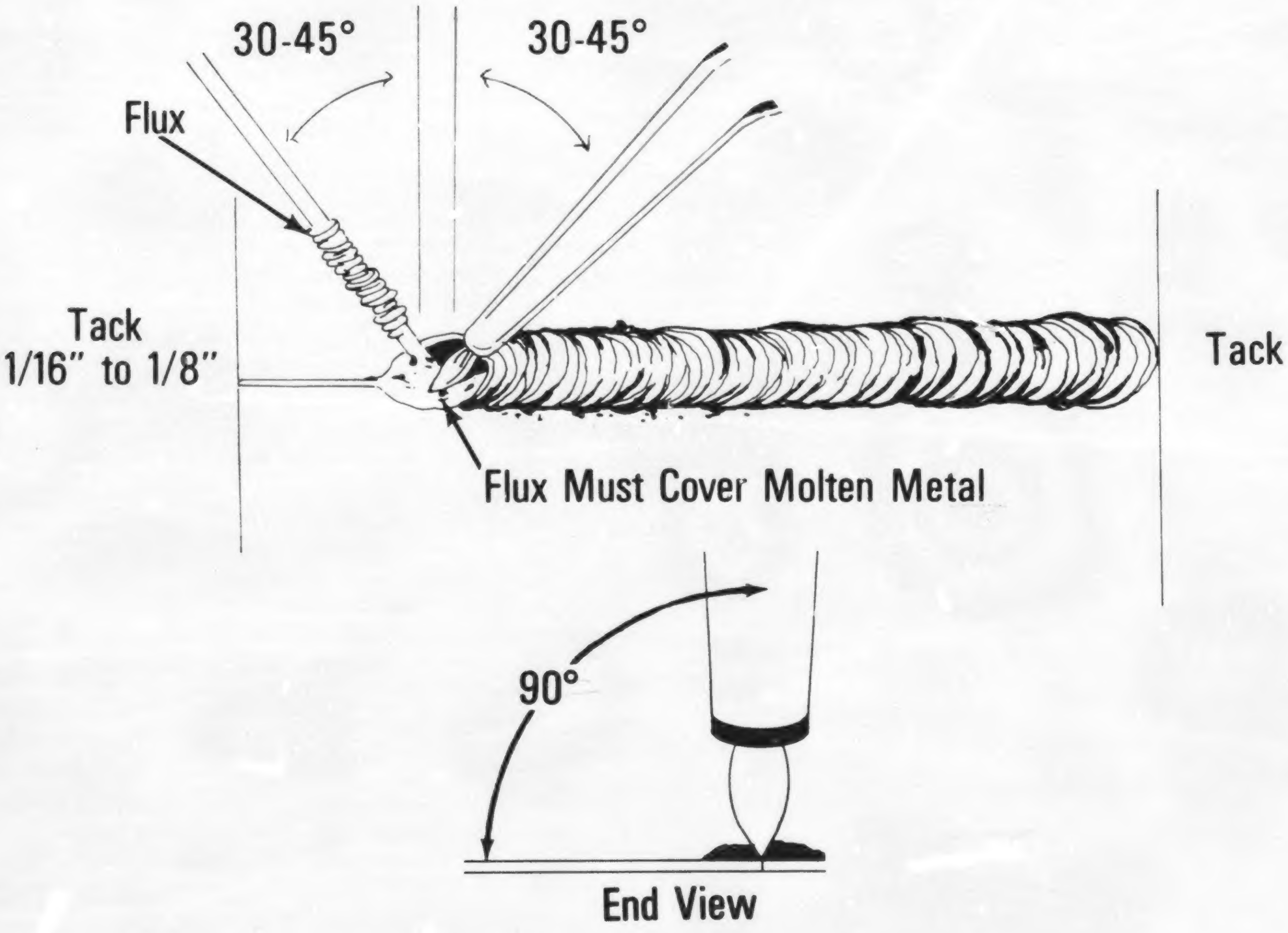
VI. Purposes for using flux

- A. Clean the base metal chemically
- B. Prevent oxidation of filler metal
- C. Float and remove oxides already present
- D. Increase flow of filler metal
- E. Increase ability of filler metal to adhere to the base metal
- F. Bring the filler metal into immediate contact with metals being joined
- G. Permit the filler metal to penetrate the pores of the base metal

VII. Reaction of molten bronze at different temperatures

- A. Too hot--The molten bronze will tend to boil and form little balls
- B. Too cool--The molten bronze will form into drops rather than flowing evenly over the surface
- C. Correct--The molten bronze will spread evenly and flow over a considerable area

Braze Welding A Butt Joint


30-45°
30-45°
Flux
Tack
1/16" to 1/8"
Tack
Flux Must Cover Molten Metal
90°
End View

OXYACETYLENE BRAZE WELDING
UNIT IV

JOB SHEET #1--BRAZE WELD A SQUARE GROOVE BUTT JOINT

I. Tools and materials

A. Oxyacetylene welding unit

B. Appropriate gloves

C. Safety glasses

D. Goggles with No. 5 lenses

E. Welding tip (according to manufacturer's recommendations)

F. Wire brush

G. Flint lighter

H. Firebrick

I. Mild steel, 2 strips of 1/8" thick and 1 1/4" x 6"

J. Bronze filler rod (according to manufacturer's recommendations)

K. Welding flux

L. Acetylene valve wrench

II. Procedure

(CAUTION: Follow all shop safety procedures.)

A. Clean metal

B. Place metal in brazing position, 1/16" to 1/8" apart

C. Turn on oxyacetylene unit

D. Adjust proper working pressure of oxygen and acetylene

(NOTE: Use manufacturer's recommendations.)

E. Place metal on firebrick

(NOTE: Do not lay metal flat on brick. Arrange metal so a small space will be between the base metal and the firebrick.)

F. Light and adjust torch to a neutral or slightly oxidizing flame

JOB SHEET #1

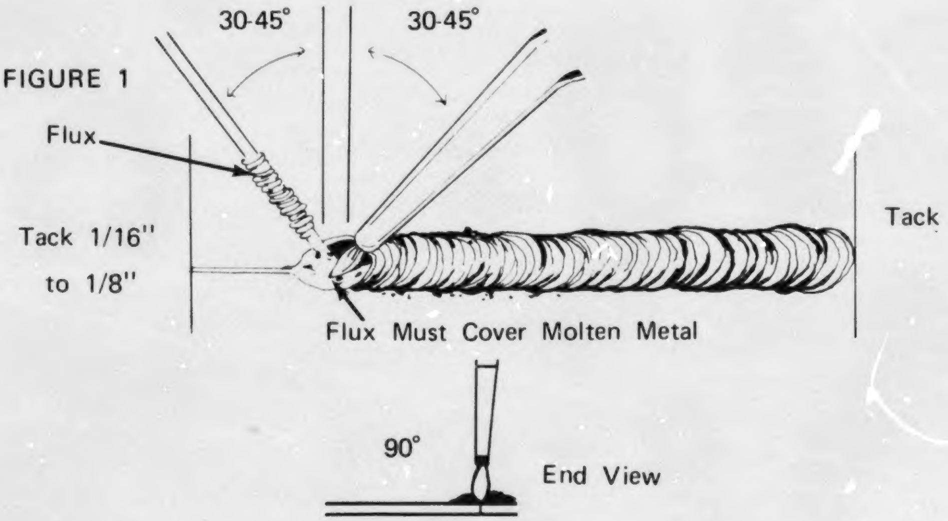
G. Preheat the end of the brazing rod and dip in the flux or use fluxed rod

H. Tack metal in place using braze filler metal

I. Heat the surface of the weld area slightly

J. Hold torch 30° to 45° vertically; hold filler rod at same angle in opposite direction (Figure 1)

FIGURE 1



K. Melt a small amount of bronze rod onto the surface and allow it to spread along the entire seam when a cherry red color occurs

L. Start depositing the proper size bead when the base metal is tinned sufficiently

(NOTE: When metal is not hot enough, the bronze will form into drops; when metal is too hot, bronze tends to boil.)

M. Complete the weld

N. Have instructor inspect weld

O. Practice doing other welds

OXYACETYLENE BRAZE WELDING
UNIT IV

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Capable of being drawn or stretched out

______b. Chemical used to clean metals and to promote fusion during the welding process

______c. Property of metals which allows them to be bent or permanently distorted without rupture; opposite of brittleness

______d. Heating the base metal to a dull red color and depositing a bead over the seam (joint) with a bronze filler rod; the base metal is not melted

______e. Melting a small amount of bronze rod onto the surface and allowing it to spread along the entire seam (joint)

1. Flux
2. Braze welding
3. Malleability
4. Tinning operation
5. Ductile

2. List three advantages and three disadvantages of braze welding.

a. Advantages

1) ______________________________

2) ______________________________

3) ______________________________

b. Disadvantages

1) ______________________________

2) ______________________________

3) ______________________________

3. List three advantages of having a chemically clean metal surface in braze welding.

a. ______________________________

b. ______________________________

c. ______________________________

4. Select methods for removing oxides from a clean metal surface by placing an "X" in the appropriate blanks.

______a. Wire brush

______b. Hammer

______c. Acid

______d. Grinder

______e. Flux

______f. Water

5. Differentiate between braze welding and fusion welding by placing an "X" next to the descriptions of braze welding.

______a. Base metal is melted and joined

______b. An alloy rod is used to lay a thin coat of bronze along the seam

______c. Rod with similar characteristics of base metal must be used

______d. The base metal is not melted

6. List five purposes for using flux.

a. ____

b. ____

c. ____

d. ____

e. ____

7. Match temperatures of molten bronze on the right with the correct reactions.

______a. The molten bronze will tend to boil and form little balls

______b. The molten bronze will form into drops rather than flowing evenly over the surface

______c. The molten bronze will spread evenly and flow over a considerable area

1. Too cool

2. Correct

3. Too hot

8. Demonstrate the ability to braze weld a square groove butt joint.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

OXYACETYLENE BRAZE WELDING
UNIT IV

ANSWERS TO TEST

1. a. 5
   b. 1
   c. 3
   d. 2
   e. 4

2. Any three from each group:

   a. Advantages

      1) Provides less chance of destroying main characteristics of base metal since it is not heated to a molten condition
      2) Consumes less gas
      3) Can be used on thin metals
      4) Used on malleable castings
      5) Increases speed of joining metals
      6) May be used to join different kinds of metals

   b. Disadvantages

      1) Cannot be used on metal where stress is a factor
      2) Expensive to use
      3) Not recommended for parts which are raised to temperatures higher than the melting point of bronze, either in service or during heat treatment
      4) Will not bond unless base metal has corrosion-resistant properties similar to bronze

3. a. Ensures that the molten bronze will stick to the base metal
   b. Has a stronger bond on base metal
   c. Allows bronze to flow smoothly and evenly over entire weld area

4. a d, e

5. b, d

6. Any five of the following:

   a. Clean the base metal chemically
   b. Prevent oxidation of filler metal
   c. Float and remove oxides already present
   d. Increase flow of filler metal
   e. Increase ability of filler metal to adhere to the base metal
   f. Bring the filler metal into immediate contact with metals being joined
   g. Permit the filler metal to penetrate the pores of the base metal

7. a. 3
   b. 1
   c. 2

8. Performance skills evaluated to the satisfaction of the instructor